Heirloom Tomato Production in Conventional and Transitional-organic Managed Systems

Paul B. Francis¹ and C. Robert Stark, Jr.

School of Agriculture, University of Arkansas at Monticello, 1408 Scogin Drive, Monticello, AR 71656

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Abstract. Demand for heirloom tomatoes (*Solanum lycopersicum* L.) and organically grown produce is increasing. The objective of this research was to compare heirloom tomato production in conventional (CS) and organic-transitional (OS) production systems. Heirloom cultivars Arkansas Traveler—the original, Cherokee Purple, Kentucky Beefsteak, Manulucie, and Persimmon Orange were grown in 2007 and 2008 on a raised bed, microirrigated, black plastic mulch culture in a split-plot design with production system as the main plot. Inorganic fertilizer at 160N–13P–50K kg·ha⁻¹ [NH₄NO₃, Ca(H₂PO₄)₂, KCl] or poultry litter (PL) at 5600 kg·ha⁻¹ was applied in March and soil-incorporated. Transplanting occurred on 12 Apr. 2007 and 22 Apr. 2008. PL supplied 194N–133P–183K and 145N–83P–171K kg·ha⁻¹ potential in 2007 and 2008, respectively. Overall, there were no system effects on total marketable fruit weight, marketable fruit numbers, average fruit weights, total cull weights, or percent marketable yields. Marketable yields averaged across systems ranged from 8,457 to 13,550 kg·ha⁻¹ in 2007 and 1,224 to 5,974 kg·ha⁻¹ in 2008. Weather-delayed transplanting followed by wet and cloudy weather in April and May and greater incidence of tomato spotted wilt virus (TSWV) were suspected for lower yields in 2008. Petiole sap nitrate-N of whole plot treatments were considered within sufficiency levels for both systems when checked at pre- and early harvest. Soil pH of the CS dropped from 7.2 to 5.6 after two seasons but did not change in the OS. Organic production of heirloom tomatoes using PL yielded equivalently to conventional culture for 2 years after transition from conventional management.

Consumer demand for heirloom and organically grown local produce is increasing and market price premiums associated with these value-added characteristics may provide profitable ventures. The increased popularity of heirloom tomatoes (*Solanum lycopersicum* L.) that began in the late 20th century has been attributed to the return to organic, local, and “authentic” foods, promotion by popular chefs, and portrayal by popular print as a symbol of elite status but accessible by non-elites (Jordan, 2007). In one e-mail survey, production method (organic or conventional) had a lower relative importance than tomato type, but the authors noted that participants younger than 38 years placed more importance on production method, lycopene content, and tomato type than older respondents (Simonne et al., 2006). These observations suggest

that future generations of fresh-market tomato consumers will be more demanding of value-added characteristics.

Organically grown produce is thought to be more nutritious by some consumers. Fresh matter content of vitamin C, carotenoids, and polyphenol contents of organically produced tomatoes was higher than conventionally grown; however, the dry matter values were not significantly different nor were plasma levels of the antioxidants vitamin C and lycopene different for subjects consuming tomato purees for 3 weeks (Caris-Veyrat et al., 2004). Antioxidant microconstituents of tomatoes were found to be related more to cultivar and growing season environment than to production system (Chassy et al., 2006). Pieper and Barrett (2009) reported that organic production systems may delay maturity and alter total and soluble solids of processing tomatoes compared with conventional systems, but nutrient content was not significantly different between production systems. Some consumers may prefer the taste of organically grown tomatoes to conventional produce. However, in one study, consumers indicated that conventionally grown tomatoes had a stronger flavor, but the overall appeal was the same for both systems (Zhao et al., 2007). Consumer taste preferences for heirloom tomatoes may be

greater than conventional cultivars. In a sensory evaluation of four unlabeled heirloom tomatoes and a popular commercial fresh-market hybrid, heirloom cultivars rated higher overall in taste preference than the commercial hybrid cultivar (unpublished data).

Organic tomato production systems can be more profitable than conventional managed systems, but only if price premiums exist for organically certified produce (Clark et al., 1999). Organic tomato production systems have been found to use less energy than conventional systems (Turhan et al., 2008). One of the major challenges to organic production of tomatoes is disease management. There are established strategies for organic producers to minimize disease pressure. Grafting of heirloom cultivars to disease-resistant rootstock has been successful at controlling soilborne diseases (Rivard and Louws, 2008). Aboveground disease incidence was reduced by using composted cotton gin trash, swine manure, and rye-vetch green manure compared with bare soil and incorporated synthetic fertilizers (Bulluck and Ristaino, 2002). Several disease control products used in organic production systems have been found to reduce early blight [*Alternaria solani* (Ell. & Mart.)] and Septoria leaf spot (*Septoria lycopersici* Speg.) compared with an untreated control (Wszelaki and Miller, 2005). Fruit quality of a modern fresh market cultivar in conventional tomato production systems was higher than organic, although yields were similar (Colla et al., 2000). Although yields of heirloom tomatoes are often less than modern commercial hybrids, consumer demand and premium prices for heirlooms and organically produced produce and the relaxed grade standards may provide a viable source of additional revenue for tomato producers. There is limited research on production of heirloom tomatoes in organic and conventional systems, especially in the southern United States, and some uncertainty of the risks involved. The objectives of this research were to investigate yield and quality of selected heirloom cultivars in conventional and PL-based transitional-organic production systems.

Materials and Methods

Field studies were conducted in 2007 and 2008 at the University of Arkansas at Monticello near Monticello, AR (lat. 33°35' N, long. 91°48') on a Tippah loam soil (fine-silty, mixed, thermic, Aquic Paleudalfs). The study site had been in conventional drip-irrigated plasticulture tomato production research for five seasons before 2007. Prior soil fertility management involved soil sampling in early September and granular fertilizer amendments according to University of Arkansas soil test recommendations. Pelleted agriculture lime was broadcast at 2000 kg·ha⁻¹ equivalent in Nov. 2006. The experimental design was a split plot with four replications. The main plot treatment was cultural system, either CS or OS, with cultivar as the split-plot treatment. Tomatoes

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¹To whom reprint requests should be addressed; e-mail francis@uamont.edu.

were grown in raised black polyethylene-covered beds, 0.15 m high $\times$ 0.91 m wide, and drip-irrigated using one offset dripline T-tape. Soil moisture was monitored using ceramic-tipped tensiometers placed at 0.15 m depth and irrigation was initiated at mean soil water tension of 35 kPa. Dripline output was measured for each main plot before transplanting using a collection container placed beneath an emitter orifice. Irrigation output (cm) was calculated from the row length, number of orifices, orifice output ($\text{cm}^3 \cdot \text{h}^{-1}$), and a mulched bed width of 91 cm. In a typical event, 0.6 cm water was applied. In 2007, the study site received 46 cm rainfall + 7 cm irrigation for a total of 53 cm. In 2008, the study site received 35 cm rainfall + 18 cm irrigation for a total of 53 cm.

Four rows, 33.5 m long $\times$ 2.44 m apart, were divided in half by a 2.0-m alley. Block one consisted of the first half of rows one and two, block two the first half of rows three and four, block three the second half of rows three and four, and block four the second half of rows one and two. Main plot treatments were randomly assigned to row halves and a random arrangement of heirloom cultivars assigned to the split plot. Subplots were 2.44-m row length and consisted of four plants spaced 0.61 m apart. Rows were staked every two plants with alternating wood stakes, 2.0 m long, and 2.1-m long metal "T-posts" for extra support. Plants were trained with plastic twine using a weave method. The field layout established in 2007 was maintained in 2008 in the same locations. Field transplants of greenhouse-grown seedlings occurred on 12 Apr. 2007 and 22 Apr. 2008. At early fruit set, plants were pruned to the first main branch fork, usually three to four suckers per plant. Cultivars used were Arkansas Traveler—the original (AT), Cherokee Purple (CP), Kentucky Beefsteak (KB), Manulucie (MN), and Persimmon Orange (PO). These cultivars were selected based on previous evaluations of 12 heirloom cultivars. The fruit from breaker to ripe were hand-harvested and graded into marketable and cull and then weighed within 2 h of harvest. Marketable fruit were defined as having the basic size, shape, and color of the specific cultivar with no visible deformations such as blossom end-rot, open wounds, or severe deformation or discoloration. For example, AR Traveler—the original is predominantly medium, 'Cherokee Purple' extralarge (U.S. Department of Agriculture, 2006), and 'Persimmon Orange' a large beefsteak jumbo (greater than 8.9 cm diameter) in size. The same person graded all fruit for both seasons. Five harvests occurred between 19 June and 14 July 2007 and five harvests between 27 June and 16 July 2008. Field yield conversions were based on a 4 $\times$ 1 skip-row planting arrangement.

Fresh poultry litter (broiler house) was applied at the rate of 5600 $\text{kg} \cdot \text{ha}^{-1}$ to the OS and inorganic fertilizer at the rate of 160N–13P–50K $\text{kg} \cdot \text{ha}^{-1}$ from granular NH_4NO_3 , triple super phosphate [$\text{Ca}(\text{H}_2\text{PO}_4)_2$], and KCl to the CS on 8 Mar. 2007 and 28 Mar. 2008. Amendments were rotovated into the

beds and the rows mulched with 25.4 μm black plastic. Three random subsamples of the PL were sent to the University of Arkansas Agricultural Diagnostic Laboratory each season for elemental analysis of nitrogen (N), phosphorus (P), and potassium (K) using standard methods (Peters et al., 2003). Average N–P–K applied from the PL was 194N–133P–183K $\text{kg} \cdot \text{ha}^{-1}$ in 2007 and 145N–83P–171K $\text{kg} \cdot \text{ha}^{-1}$ in 2008. It is difficult to predict exactly how much of the organic N from the poultry litter was mineralized to plant-available form, but researchers have documented N mineralization rates ranging from 43% to 51.5% within 14 to 120 d after incorporation (Abbasi et al., 2004; Cabrera et al., 1994). Petiole sap $\text{NO}_3\text{-N}$, extracted from the most recently matured leaf, and soil $\text{NO}_3\text{-N}$ in the upper 8 cm from a 2:1 distilled H_2O :soil mix were measured for main plot replicates at pre- and midharvest using a Cardy® handheld selective ion meter (Spectrum Technologies Inc., Plainfield, IL). Two petioles from each subplot were collected and sampling was performed between 0800 and 0900 HR as a result of the daily rhythms that may occur (Ferrario et al., 1992). Leaf and soil samples were pooled over split-plot treatments. Composite soil samples from the upper 15 cm were collected for each main plot replicate in the mulch row from 10 1.9-cm diameter cores, two cores per cultivar subplot, in early September at the end of the season before mulch removal and thoroughly mixed in a clean container.

This sampling scheme was consistent with the previous soil testing program. Samples were extracted with a Mehlich-3 solution (Mehlich, 1984) and analyzed for elemental concentration by inductively coupled plasma atomic emission spectroscopy and pH from a 2:1 distilled water:soil mixture at the University of Arkansas Soil Testing Laboratory.

The site was scouted twice a week for insect and disease pest presence and appropriate control substances applied as needed based on observation of pests in the study site in addition to preventive disease control applications. A basal-directed application of 225 mL of strobilin fungicide at a concentration of 0.22 $\text{mL} \cdot \text{L}^{-1}$ was applied to each plant on 9 May 2007 and 9 May 2008 to the CS as a preventive disease control. Cupric hydroxide was applied three times per season to all systems at 11.5 $\text{g} \cdot \text{L}^{-1}$ and a spray rate of 179 $\text{L} \cdot \text{ha}^{-1}$ for preventive disease control. One application of Bt (*Bt-kurstaki*) insecticide was applied on 11 June 2007 to all systems at a concentration of 184 $\text{g} \cdot \text{L}^{-1}$ and application rate of 179 $\text{L} \cdot \text{ha}^{-1}$ for armyworm (*Pseudaletia unipuncta* Haworth) control. In 2008, one application of clarified hydrophobic extract of neem oil, an extract from the neem tree (*Azadiracta indica* A. Juss), was applied at a concentration of 8.3 $\text{mL} \cdot \text{L}^{-1}$ and an application rate of 179 $\text{L} \cdot \text{ha}^{-1}$ to all systems on 20 May 2008 for control of potato aphids [*Macrosiphum euphorbiae* (Thomas)]. Bifenthrin insecticide was applied at a concentration of 3.1 $\text{g} \cdot \text{L}^{-1}$ and application rate

of 179 $\text{L} \cdot \text{ha}^{-1}$ to the CS on 16 June 2008 and 27 June 2008 for brown stinkbug [*Euschistus servus* (Say)] control. Row alleys were cultivated twice each season for weed suppression using a walk-behind self-propelled rototiller having a 0.61-m width. Rainfall was recorded on-site with an Acu-Rite™ (Chaney Instruments, Lake Geneva, WI) visually read rain gauge with a 9.7-cm² orifice and temperature with a Watchdog® Model 110 (Spectrum Technologies Inc.) air temperature data logger.

Fruit yields of the five harvests were summed and fractioned into total marketable weight (MktWt), total number of marketable fruit (MktNo), and total weight of culled fruit (CullWt). Average weight of marketable fruit (MktAve) was determined by dividing the total weight by fruit number, and percent marketable fruit (MktPer) by dividing total marketable weight by the sum of total marketable weight and total weight of culled fruit. Yield data were analyzed as a randomized complete block split-plot design using a mixed model. Year, system, and cultivar were considered fixed and block and block $\times$ system random variables. System and cultivar were considered fixed and block and block $\times$ system random variables. An analysis of variance of petiole and soil nitrate-N and soil test data were performed for each sampling to test for system effects because the data were collected across the whole plot treatments. All data analyses were performed using SAS Version 9.1.3 (SAS Institute Inc., Cary, NC).

Results and Discussion

In 2008, pre-transplant rains delayed field operations and transplanting by 10 d compared with 2007. Plants were taller, thinner, and more root-bound when set out in 2008 than in 2007, and wet and cloudy weather continued for $\approx$ 1 week after transplanting (Table 1). Rainfall in Apr. 2008 was nearly two times greater than in Apr. 2007. Although July rainfall was greater in 2007 than in 2008, harvesting was well underway and the rain did not hamper field activities. Average monthly air temperature between 2007 and 2008 was less than 1 °C different from April to June but 2.3 °C lower in July 2007 than July 2008 as a result of more cloudy weather. Plant mortality was similar between CS and OS across cultivars for both seasons. Plant mortality losses were greater

Table 1. Weather summary at the University of Arkansas horticulture plots from transplant to final harvest, 2007 and 2008 seasons.

Year ^z	Month				Total
	April	May	June	July	
Rainfall (mm)					
2007	91	108	18	241	458
2008	173	107	79	20	379
Average temperature (°C)					
2007	15.8	22.6	26.6	26.3	
2008	16.7	21.8	26.4	28.6	

^aField transplanting occurred on 12 Apr. 2007 and 22 Apr. 2008.

in 2008 as a result of increased incidence of the TSWV. Four plants were lost to TSWV in 2007 compared with 31 plants lost in 2008. Incidences of early blight [caused by *Alternaria solani* (Ell. & Mart.) L. R. Jones & Grout] and Southern blight (caused by *Sclerotium rolfsii* Sacc.) were higher in 2008 compared with 2007. Additionally, six KB plants were lost from tomato mosaic virus in 2008, which was thought to have originated from contaminated seed.

Soil test results of the main plots in the fall of 2006, before any soil amendments, were not different as expected, but there were some differences by the end of the experiment. After two seasons of PL or inorganic granular fertilizer, the exchangeable K levels were higher and soil pH more acidic ($P < 0.05$) in the CS (data not shown). The amount of K applied from the PL was 10 times greater in 2007 and six times greater in 2008 than that applied from granular fertilizer. However, soil test K levels measured in the OS are influenced by the amount of K mineralized during the season. Soil acidity in the CS may have increased as a result of the acidic nature of the N carrier used (NH_4NO_3) and the concentrated banded placement in the row, where the fall soil samples were obtained.

There were significant ($P < 0.01$) year effects on MktWt, MktNo, and CullWt, but no year effects were observed for MktAve or MktPer or system and system interactions in the overall analysis of variance (ANOVA) (Table 2). However, there were cultivar effects ($P < 0.01$) on all yield attributes measured. A year $\times$ cultivar effect ($P < 0.01$) occurred for MktNo and CullWt. A line graph (not shown) suggested that the interaction was most likely the result of the MN cultivar, which had relatively fewer MktWt and CullWt in 2008 than 2007 with respect to the patterns observed for the other cultivars. Because there was a year and cultivar effect in the overall ANOVA, the yield attributes of the cultivars for each year were averaged across systems for comparisons (Table 3). Overall, yields of MktWt and CullWt were lower in 2008 than in 2007. This was attributed to less favorable growing conditions in Apr. 2008 and greater disease incidences in the 2008 season. End-of-season plant mortality in 2008 averaged 29.4% across systems and cultivars compared with just 3.8% in 2007 and was not influenced by system or cultivar (analysis not shown). In 2008, 67% of plants lost were the result of TSWV. Heirloom tomatoes are susceptible to TSWV and incidences of this disease can vary unpredictably from year to year (Riley et al., 2011). The data illustrate the extreme production variability and risks associated with growing heirloom tomatoes, regardless of production system used. The KB cultivar had lower MktWt than AT or CP in 2007, and AT had greater MktWt than the other cultivars in 2008. The AT cultivar also had a higher MktPer of 61% than the other cultivars in 2007 and 64% in 2008. As expected, the beefsteak cultivars KB and PO had greater individual MktAve than the smaller fruited cultivars AT and MN and

seemed more prone to bruising if handled too rough during harvest and transport. Generally, the large-fruited beefsteak heirloom cultivars require more care during harvest and transport to prevent injury. CullWt was greater for CP than the other cultivars in 2007 and 2008. CP is the earliest maturing of the cultivars and seemed more prone to incomplete fertilization, resulting in deformed fruit and cracking. AT and MN were later-maturing than the other cultivars in the study.

Petiole sap nitrate-N of the most recently matured leaf on 22 May 2007 and 20 May 2008 samplings were within the 400 to 600 $\mu\text{g}\cdot\text{g}^{-1}$ sufficiency range for petiole “quick tests” (Hochmuth et al., 1991) for both systems (Table 4). The petiole nitrate-N of the OS was lower ($P < 0.01$) than the CS on 22 May 2007 at the beginning of the study and tended to be lower in subsequent samplings, but not significantly. June samplings occurred during harvest and the petiole sap nitrate-N concentrations were lower than in May as expected

and there were no system effects. Soil nitrate-N was generally higher in the CS at all samplings but only significant ($P < 0.05$) in the 11 June 2008 sampling. In 2008, there may have been some upward wicking and precipitation of fertilizer nitrate-N because the dripline in 2008 was installed in the soil at 0.10-m depth in contrast to surface placement in the 2007 season. We also noticed a distinct white precipitate on the soil surface of the CS plots in 2008 that was not observed in the OS plots when the plastic mulch was removed post-harvest. Nitrate-N from fertilizer can concentrate in certain regions under plastic mulch as a result of soil and dripline placement. Soil $\text{NO}_3\text{-N}$ accumulation was observed on the drier side of the bed in a soil with a narrow wetting pattern (Cook and Sanders, 1990). Our findings suggest that management system and dripline placement can influence soil chemistry.

Marketable yields of heirloom tomatoes in a transitional-organic crop management

Table 2. Analysis of variance for total marketable fruit weight (MktWt), total number of marketable fruit (MktNo), average weight of marketable fruit (MktAve), total weight of culled fruit (CullWt), and percent marketable fruit harvested (MktPer) for five heirloom tomato cultivars grown in conventional or organic-transitional systems in Arkansas, 2007 and 2008.

Source	df	MktWt	MktNo	MktAve	CullWt	MktPer
Year	1	<0.001	<0.001	NS	<0.001	<0.001
System	1	NS	NS	NS	NS	NS
Cultivar	4	<0.001	<0.001	<0.001	<0.001	<0.001
Year $\times$ system	1	NS	NS	NS	NS	NS
System $\times$ cultivar	4	NS	NS	NS	NS	NS
Year $\times$ cultivar	4	NS	<0.001	NS	<0.001	NS
Year $\times$ system $\times$ cultivar	4	NS	NS	NS	NS	NS

NS = nonsignificant.

Table 3. Total marketable fruit yield (MktWt), total number of marketable fruit (MktNo), average weight of marketable fruit (MktAve), total weight of culled fruit (CullWt), and percent marketable fruit (MktPer) of five heirloom cultivars averaged across conventional and organic-transitional production systems in Arkansas, 2007 and 2008.

Year	Cultivar	MktWt ^z (kg·ha ⁻¹)	MktNo (no./plant)	MktAve CullWt ----- (kg·ha ⁻¹) -----	MktPer (%)	
2007	Arkansas Traveler	13,550 a	8.59 a	0.159 a	9.220 a	61 a
	Cherokee Purple	12,500 a	3.80 c	0.333 b	21.306 c	37 bc
	Kentucky Beefsteak	8,457 b	1.95 c	0.418 c	15.257 b	34 c
	Manulucie	10,213 ab	5.50 b	0.189 a	16.825 b	37 bc
	Persimmon Orange	11,594 ab	2.77 c	0.419 c	13.233 b	46 b
2008	Arkansas Traveler	5,974 a	4.22 a	0.142 a	3.272 b	64 a
	Cherokee Purple	4,027 b	1.28 b	0.324 bc	5.862 a	39 b
	Kentucky Beefsteak	1,224 b	0.27 c	0.469 c	1.713 c	32 b
	Manulucie	2,308 b	1.03 bc	0.216 ab	2.336 bc	45 ab
	Persimmon Orange	2,575 b	0.57 c	0.464 c	2.154 bc	48 ab

^aMeans followed by the same letter within year are not significantly different at $P < 0.05$.

Table 4. Leaf and soil nitrate-N monitoring, 2007 and 2008.

Date	System	Leaf ----- (μg·g ⁻¹) -----	Soil
22 May 2007	Conventional	645	92
	Organic	463**	50 NS
8 June 2007	Conventional	593	134
	Organic	380 NS	56 NS
20 May 2008	Conventional	700	46
	Organic	583 NS	33 NS
11 June 2008	Conventional	350	220
	Organic	267 NS	56*

NS, *, ** Nonsignificant or significant system effects within sampling date at $P \leq 0.05$ or 0.01 respectively.

Table 5. Marketable yields for 2007 and 2008.

Cultivar	Total marketable		Percent marketable	
	Conventional	Organic	Conventional	Organic
	----- (kg·ha ⁻¹) -----		----- (%) -----	
2007				
Arkansas Traveler	10,265	11,439 NS	63	59 NS
Cherokee Purple	10,256	9,765 NS	37	36 NS
Kentucky Beefsteak	7,155	6,392 NS	36	31 NS
Manulucie	8,814	7,544 NS	41	34 NS
Persimmon Orange	9,422	9,149 NS	47	46 NS
2008				
Arkansas Traveler	4,327	5,242 NS	63	65 NS
Cherokee Purple	4,589	1,861 **	48	30 NS
Kentucky Beefsteak	823	1,137 NS	21	43 NS
Manulucie	1,383	2,312 NS	41	49 NS
Persimmon Orange	2,275	1,849 NS	55	40 NS

NS, ** Nonsignificant or significant system effect for cultivar at $P \leq 0.01$.

system, using soil-incorporated PL as a nutrient source, were similar to those of a conventional system using inorganic granular fertilizer (Table 5). Organic production of heirloom tomatoes could be a potentially profitable venture for a producer, provided that proper procedures for organic production certification are followed and market price premiums for organically grown tomatoes are present. Cropping system had an impact on soil fertility as indicated by the effects of the conventional system on soil pH, K, and midharvest nitrate-N. Others noted the long-term effects of PL application on soil P and N (He et al., 2009). Soil pH and extractable P and K were at optimum levels before 2007 at the study site as a result of five seasons of annual soil testing and applications of lime and granular fertilizer according to University of Arkansas soil test recommendations. Managing the soil nutrient reservoir can be more of a challenge with organic manures as a result of the variability in nutrient concentrations and mineralization release. With the study site at optimum soil pH, P, and K, at the initiation of the research, tomato response from poultry litter is related to N mineralization. Based on petiole NO₃-N monitoring, N supply from the PL was adequate for heirloom tomato production in the two seasons of study. Understanding long-term effects of pre-mulch banded placement of granular fertilizer or manures in raised bed, micro-irrigated, plastic mulch culture systems on the soil nutrient distribution is needed. However, in the short term, PL can be used in a soil fertility program as a substitute for

inorganic granular fertilizer for the heirloom tomato cultivars studied.

Literature Cited

- Abbasi, M.K., M. Hina, A. Kahalique, and S.R. Khan. 2004. Mineralization of three organic manures used as a nitrogen source in a soil incubated under laboratory conditions. *Commun. Soil Sci. Plant Anal.* 38:1691–1711.
- Bulluck, L.R., III and J.B. Ristaino. 2002. Effect of synthetic and organic soil fertility amendments on southern blight, soil microbial communities, and yield of processing tomatoes. *Phytopathology* 92:181–189.
- Cabrera, M.L., S.C. Tyson, T.R. Kelley, O.C. Pancorbo, W.C. Merka, and S.A. Thompon. 1994. Nitrogen mineralization and ammonia volatilization from fractionated poultry litter. *Soil Sci. Soc. Amer. J.* 58:367–372.
- Caris-Veyrat, C., M.J. Amiot, V. Tyssandier, D. Grasselly, M. Buret, M. Mikolajczak, J.C. Guillard, C. Bouteloup-Demange, and P. Borel. 2004. Influence of organic versus conventional agricultural practice on the antioxidant micro-constituent content of tomatoes and derived purees; consequences on antioxidant plasma status in humans. *J. Agr. Food Chem.* 52: 6503–6509.
- Chassy, A.W., L. Bui, E.N.C. Renaud, M. Van Horn, and A.E. Mitchell. 2006. Three-year comparison of the content of antioxidant microconstituents and several quality characteristics in organic and conventionally managed tomatoes and bell peppers. *J. Agr. Food Chem.* 54:8244–8252.
- Clark, S., K. Klonsky, P. Livingston, and S. Temple. 1999. Crop-yield and economic comparisons of organic, low-input, and conventional farming systems in California's Sacramento valley. *Amer. J. Altern. Agr.* 14:109–121.

- Colla, G., J.P. Mitchell, B.A. Joyce, L.M. Huyck, W.W. Wallender, S.R. Temple, T.C. Hsiao, and D.D. Poudel. 2000. Soil physical properties and tomato yield and quality in alternative cropping systems. *Agron. J.* 92:924–932.
- Cook, W.P. and D.C. Sanders. 1990. Fertilizer placement effects on soil nitrogen and use by drip-irrigated and plastic-mulched tomatoes. *HortScience* 25:767–769.
- Ferrario, S., I. Agius, and A. Morisot. 1992. Daily variations of the mineral composition of xylemic exudates in tomato. *J. Plant Nutr.* 15:85–98.
- He, Z., C.W. Honeycutt, I.A. Tazisong, Z.N. Senwo, and D. Zhang. 2009. Nitrogen and phosphorus accumulation in pasture soil from repeated poultry litter application. *Commun. Soil Sci. Plant Anal.* 40:587–598.
- Hochmuth, G., D. Maynard, C. Vavrina, and E. Hanlon. 1991. Plant tissue analysis and interpretation for vegetable crops in Florida. Fla. Coop. Ext. Serv. Special Series SS-VEC-42.
- Jordan, J. 2007. The heirloom tomato as cultural object: Investigating taste and space. *Sociol. Ruralis* 47:20–41.
- Mehlich, A. 1984. Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. *Commun. Soil Sci. Plant Anal.* 15:1409–1416.
- Peters, J., S. Combs, B. Hoskins, J. Jarman, J. Kovar, M. Watson, A. Wolf, and N. Wolf. 2003. Recommended methods for manure analysis (A3769). Univ. Wisconsin Cooperative Extension Service, Madison, WI.
- Pieper, J.R. and D.M. Barrett. 2009. Effects of organic and conventional production systems on quality and nutritional parameters of processing tomatoes. *J. Sci. Food Agr.* 89:177–194.
- Riley, D.G., A. Sparks, Jr., and D. Langston. 2011. Managing tomato spotted wilt in tomato in Georgia. Univ. Georgia Coop. Ext. Ser. Cir. No. 1002. May 2011.
- Rivard, C.L. and F.J. Louws. 2008. Grafting to manage soilborne diseases in heirloom tomato production. *HortScience* 43:2104–2111.
- Simonne, A.H., B.K. Behe, and M.M. Marshall. 2006. Consumers prefer low-priced and high-lycopene- content fresh-market tomatoes. *Hort-Technology* 16:674–681.
- Turhan, S., B.C. Ozbag, and E. Rehber. 2008. A comparison of energy use in organic and conventional tomato production. *J. Food Environ.* 6:318–321.
- U.S. Department of Agriculture. 2006. United States standards for grades of fresh tomatoes. 7 CFR 51.1855-51.1877.
- Wszelaki, A.L., and S.A. Miller. 2005. Determining the efficacy of disease management products in organically-produced tomatoes. *Plant Health Prog.* doi:10.1094/PHP-2005-0713-01-RS.
- Zhao, X., E. Chambers, IV, Z. Matta, T.M. Loughin, and E.E. Carey. 2007. Consumer sensory analysis of organically and conventionally grown vegetables. *J. Food Sci.* 72:S87–S91.