Variety Trials

Evaluation of Tomato Varieties under Organic Production Practices in Georgia

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SUMMARY. Tomato (*Solanum lycopersicum*) is a popular crop among organic growers, particularly open-pollinated varieties; however, there is a lack of information evaluating these varieties in comparison with commercial F₁ hybrids. This study was undertaken to compare conventionally produced commercial F₁ tomato varieties available in the southeastern United States with open-pollinated varieties popular among organic growers. Nineteen tomato varieties were evaluated in 2011 and 2012 using the U.S. Department of Agriculture National Organic Program guidelines; however, the land used had not been in 3 years of organic production. Staked tomatoes were grown on plastic mulch. Data collected included early and total graded yield. In general, F₁ hybrid, determinate or semideterminate varieties, had the best early and total yields compared with open-pollinated varieties. HSX 8115H and 'Celebrity' had the highest early total yield. 'Costoluto Fiorentino', an open-pollinated variety, also had good early total yield, but significantly less than HSX 8115H or 'Celebrity'. 'Costoluto Fiorentino' was the only open-pollinated variety among the five highest yielding varieties for early total yield. In addition, 'Celebrity' had the greatest total yield of all the entries tested. All of the top five varieties for total yield were F₁ hybrids and either determinate or semideterminate types. 'Costoluto Fiorentino' had total yield of 22,046 lb/acre, which was 14.3% lower than the lowest yielding variety in the top five yielding varieties. 'Florida Pink' had the largest average fruit weight, which also had the lowest total yield of all the entries. Although the open-pollinated varieties, popular among organic and local growers, yielded less than F₁ hybrids, they may possess characteristics of color, flavor, or texture that are desired and were not evaluated in this study. This may be an opportunity for plant breeders to develop varieties desired by local organic growers that have unique characteristics, in addition to high yields and disease resistance.

Tomato is an important crop in the United States with 105,700 acres of fresh tomatoes harvested and 327,800 acres of processed tomatoes valued at \$2.5 billion [U.S. Department of Agriculture (USDA), 2009]. In Georgia, tomato production is valued at \$33.5 million and is produced on 3400 acres (Wolf and Shepherd, 2012).

Organic farming has seen a surge in production in the last 15–20 years. From 1992 to 2008, total certified farm land has increased 5-fold from around 900,000 acres to 4.8 million acres (USDA, 2008). The Georgia Department of Agriculture lists 2438 acres (M. Evans, personal communication) in organic production. Certified organic growers in Georgia are

required to register with the Georgia Department of Agriculture; however, they are not required to report acres and about half of the 124 certified organic farms did not report acreage. In addition, many growers do not obtain certification from the USDA or use an alternative certification such as Certified Naturally Grown (J. Gaskin, personal communication). Although it is impossible to ascertain the number of organic acres in Georgia, it is probably in the range of 4000–5000 acres. This increase in organic production has resulted in an increase in research efforts in this area; however, there continues to be a growing need for organic research that can help this agricultural sector.

Variety evaluation is one area that can be helpful for organic producers. Several such studies have been conducted by researchers around the world examining different aspects of variety performance under organic conditions. Organic variety evaluations have occurred in Italy, India, Spain, Croatia, Poland, France, and the United States (Campanelli et al., 2012; Francis and Stark, 2012; Ganesan, 2001; Gonzalez-Cebrino et al., 2011; Kapoulas et al., 2011; Piazza et al., 2003; Porteneuve et al., 2012; Ronga et al., 2011, 2012; Sánchez-Giráldez et al., 2012; Szafrrowska, 2010). Along with yield, a number of other characteristics have been investigated including fruit cracking, antioxidants such as lycopene, sugar, and vitamin C content (Aldrich et al., 2010; Bender et al., 2005; Sánchez-Giráldez et al., 2012). There continues to be a need for variety evaluations as many of the available varieties are locally adapted or only regionally available. There has been little trialing of tomato varieties under organic conditions in the southeastern United States. One study in North Carolina evaluated heirloom and hybrid tomatoes in conjunction with various production practices including organic and conventional. The heirloom variety Stupice and the hybrid NC 0652 did well under organic production, whereas NC 0652 did better under conventional production (Davis, 2007).

Efforts to develop varieties specifically for organic production have been shown to be possible with wheat [*Triticum aestivum* (Murphy et al., 2007)]. In two of the five locations evaluated in this study, conventionally

produced wheat yielded higher, while at the other three locations there was no difference in yield. However, there was a variety by production system (i.e., organic vs. conventional) interaction in four of the five locations suggesting that selection of phenotypes for organic production may be possible.

Breeding vegetables for organic production systems has been limited. Although there are many open-pollinated vegetable varieties, most commercial varieties have been developed for conventional production with an emphasis on F_1 hybrids, which often exhibit hybrid vigor and protect the breeder's investment. Organic growers are interested in open-pollinated varieties from which the seed can be easily saved. Most seed companies are reluctant to invest in such varieties because the seed of such varieties is so easily saved. Public breeding programs that filled this void by having a primary focus on developing open-pollinated varieties have been reduced over the years as resources have been diverted into biotechnology and basic research. For example, at Auburn University in the early 1980s, there were three plant breeders working on seven different horticultural crops. Today there are no plant breeders actively working on releasing new horticultural varieties at this institution. The National Association of Plant Breeders (NAPB) recommendations for improving germplasm lists field-based plant breeding capacities, second only to germplasm conservation as goals for the next 5 years (NAPB, 2011).

In a review article, Lammerts van Bueren et al. (2011) suggested several areas that should be emphasized in organic breeding programs. These included soil nutrient use efficiency, rhizosphere competence for disease resistance, weed competition, disease

resistance, insect resistance, abiotic stress tolerance, and quality.

There have been some collaborative efforts in breeding for organic production. An example is the Northern Organic Vegetable Improvement Collaborative that includes four universities, the USDA, and the Organic Seed Alliance (Oregon State University, 2013). This group has not only been active in breeding for organic production but maintains a database of organic variety trials.

As breeding efforts increase focusing on organic production, there will be an increasing need to evaluate these varieties. In addition, currently available open-pollinated tomato varieties that may be locally adapted, that have not been the focus of commercial production, will have to be evaluated. This study was undertaken to compare, under organic production practices, fresh market modern F_1 varieties commonly grown in the southeastern United States with open-pollinated varieties popular among organic growers.

Materials and methods

This study was conducted at the Durham Horticulture Farm in Watkinsville, GA (lat. 33°55'N, long. 83°25'W) on a Cecil sandy loam (Fine, kaolinitic, thermic Typic Kanhapludults) and included fresh market beefsteak-type tomato. In 2011, the experimental site was in year 2 of transition to National Organic Program (NOP) certified organic land. In 2012, the land used was not part of the NOP program and had been in conventional production before this study. In both cases, the land had not been in tomato production for at least the previous 10 years.

In 2011, untreated tomato seeds were sown in flats of organic media (Conrad Fafard, Agawam, MA) in a greenhouse on 10 Mar. 2011. In

2012, untreated seeds were sown on 8 Mar. 2012. Seedlings were grown according to NOP guidelines (USDA, 2011) and University of Georgia Cooperative Extension Service recommendations for transplant production (Boyhan and Granberry, 2010). In 2011, seedlings were fertilized with liquid fish + kelp (Neptune's Harvest, Gloucester, MA) by mixing 1 tablespoon per gallon of water. In 2012, a prepared media was used to produce the seedlings that included Fafard organic media, compost, worm castings, and perlite in about equal amounts. To this was added 3 cups/yard³ of kelp meal (Espoma Co., Millville, NJ), greensand (Fertrell Co., Bainbridge, PA), gypsum (Oldcastle Lawn & Garden, Atlanta, GA), bonemeal (Voluntary Purchasing Group, Bonham, TX), and 1 cup/yard³ bloodmeal (Voluntary Purchasing Group).

In 2011, the field was prepared with 120 lb/acre nitrogen (N), 14.4 lb/acre phosphorus (P), and 52.3 lb/acre potassium (K) by application of 8N-2.2P-4.2K (Nature Safe; Griffin Industries, Cold Springs, KY) at a rate of 1500 lb/acre applied preplant and incorporated on 25 Apr. 2011. In addition, 1 inch of compost was applied evenly over the entire site and incorporated. The compost used is produced at the University of Georgia with the primary feedstocks consisting of 60% from grounds and arbor operations and 25% from animal quarters bedding. The remainder is from various sources including paper, discarded bedding plants, and sod strips (D. Adams, personal communication). The compost has $\approx 1\%$ of N, P, and K. Beds, 6-ft on-center, were immediately formed and covered with 1-mil white on black plastic (Sigma Plastics Group, Lyndhurst, NJ) with a single drip irrigation line (8-inch emitter spacing, 0.2 gal/h at 10 psi)

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3094	cup(s)/yard ³	L·m ⁻³	3.2316
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
1.1209	lb/acre	kg·ha ⁻¹	0.8922
0.0254	mil	mm	39.3701
28.3495	oz	g	0.0353
6.8948	psi	kPa	0.1450
3.9063	tablespoon/gal	mL·L ⁻¹	0.2560

(Toro Micro-Irrigation, El Cajon, CA) under the plastic. The bed top was ≈ 3 ft across. In 2012, the field was prepared with 158, 73, and 146 lb/acre of N, P, and K, respectively, applied as 13N-0P-0K (Nature Safe, Griffin Industries), bonemeal (0N-4.4P-0K), and potassium sulfate (0N-0P-43.2K) (SQM North America, Atlanta, GA), and 1 inch of compost. This was immediately incorporated on 12 Apr. 2012. Beds were formed and covered with white on black plastic (1 mil) with a single drip irrigation line under the plastic on 13 Apr. 2012.

There were 19 varieties arranged in a randomized complete block design with three replications. Local growers in Georgia recommended the open-pollinated varieties, whereas the F_1 hybrids were varieties the respective seed companies were interested in having evaluated. Only the seed from Southern Exposure Seed Exchange (Acorn Community, VA), Seed Savers Exchange (Decorah, IA), and TomatoFest (Little River, CA) were organically produced. Each plot was 15 ft long with a single row of plants with an in-row spacing of 1.5 ft. The between-row spacing was 6 ft, and a 5-ft in-row buffer separated individual plots. Plants were not pruned and 5-ft wooden stakes were set in the soil between each plant. There was ≈ 4 ft of stake aboveground after setting. Plants were supported by three courses of string, which were interwoven between the plants and stakes as the plants grew. Plants were scouted biweekly for insect and disease damage, but chemical management was not required. In 2011, liquid fertilizer was applied to the plants 6 weeks after transplanting with 4N-1.3P-2.5K (AgGrand, Superior, WI) applied with a 100:1 chemical injector (Dosatron International, Clearwater, FL) at 10 lb/acre N. Plants were irrigated as needed based on visual and tactile assessment of soil moisture.

Plants were assessed for growth habit just before first harvest. Each plot was assessed as either indeterminate, semideterminate, or determinate. Determinate plants did not grow taller than the stakes used. Semideterminate varieties grew 1–2 ft beyond the top of the stake and indeterminate plants grew more than 2 ft longer than the stakes. Vine ripe fruit were harvested on 12, 22, 26 July and 4, 11 Aug. 2011. Early yields were calculated as those

fruit harvested on 12 and 22 July 2011. In 2012, fruit were harvested on 5, 10, 13, 17, 20, 24, 27 July and 2, 10 Aug. Fruit harvested on 5–17 July 2012 were considered early. A Kerian Speed Sizer (Kerian Machines, Grafton, ND) was used to divide the ripe tomatoes into size classes. We divided the fruit into small/medium and large/extra-large size classes delineated by the maximum diameter opening a medium-sized fruit will pass through in any position (2–17/32 inches) (USDA, 1991). These size classes will henceforth be referred to as small and large, respectively. Only marketable fruit were graded and their yield recorded.

All data were transformed with a square root transformation to normalize the data and the final results were back transformed to their original units and yields are reported as pounds per acre. StataSE 12.1 (Stata Corp., College Station, TX) was used to calculate transformations, Fisher's protected least significant difference, and coefficients of variation.

Results and discussion

There was no variety $\times$ year interaction for early total and total marketable yield, so the results from both years were combined (Table 1). HSX 8115H had the highest yield of total early fruit with 18,804 lb/acre (Table 1). This yield was significantly higher than that of 'Costoluto Fiorentino', but did not differ from that of 'Celebrity'. The six top-yielding varieties for early total fruit were significantly greater than Scarlet Red, which had total early yield of 8361 lb/acre. 'Mortgage Lifter VFN' and 'Florida Pink' had significantly lower total early yields compared with 14 of the varieties in the trial.

'Celebrity' had significantly greater total yield than all other entries in the trial with 33,574 lb/acre (Table 1). The next highest total yield was produced by 'Mountain Fresh Plus' with 28,064 lb/acre. It did not differ significantly from 'BHN 602' or 'Fletcher 0377'. Two open-pollinated varieties that had reasonably good total yield included Costoluto Fiorentino and Neptune with 22,046 and 15,436 lb/acre, respectively. Both of these open-pollinated varieties had significantly lower total yield than the top five yielding varieties.

The lowest total yielding variety was Florida Pink with 5077 lb/acre. This variety had lower yields than any other variety in the trial with the exception of Jeff Davis with 6040 lb/acre and Mortgage Lifter VFN with 7113 lb/acre.

Fruit size averaged 5.8 oz compared with beefsteak tomato fruit, which are in the 6- to 10-oz size (Jones, 2013). However, there were a few exceptions. 'Florida Pink' had the largest fruit compared with all other entries in the trial with an average fruit weight of 10.2 oz (Table 1). 'Cherokee Purple' had the next largest average fruit size of 8.4 oz, which did not differ from 'Crnkovic Yugoslavian' or 'Mortgage Lifter VFN', but did differ significantly from all other entries.

The smallest average fruit size was with 'Neptune' at 3.0 oz/fruit, which did not differ significantly from 'Ozark Pink' at 3.3 oz/fruit or 'Druzba' at 4.3 oz/fruit. 'Neptune' fruit were smaller than all other entries in the trial.

Both large early yield and large total yield had a variety $\times$ year interaction, so these results were examined separately (Table 2). 'BHN 602' and 'Mountain Fresh Plus' had the greatest early large yield in 2011 with 3071 and 2877 lb/acre, respectively. 'Scarlet Red' with 2212 lb/acre had the third highest early large yield in 2011 and was significantly different from all other entries in the trial. Three entries had no early large fruit in 2011. They include 'Druzba', 'Costoluto Fiorentino', and 'Florida Pink'.

'BHN 602' and 'Mountain Fresh Plus' produced the greatest early large yield in 2012 with 8197 and 4037 lb/acre, respectively (Table 2). 'Cherokee Purple' had the next highest early large yield in 2012 with 3075 lb/acre, which did not differ significantly from that of 'Celebrity' with 2386 lb/acre.

'Neptune' and 'Druzba' had no early large yield in 2012. 'Ozark Pink' had the lowest early large yield in 2012 with 77 lb/acre. This variety did not differ significantly from 'Costoluto Fiorentino', 'Abraham Lincoln', 'Mortgage Lifter VFN', 'RFT 80772', and 'Florida Pink'.

'BHN 602' had the greatest total large yield in 2011 at 8082 lb/acre, which was significantly more than all other varieties in 2011 (Table 2). That year, 'Mountain Fresh Plus'

Table 1. Tomato variety trial with seed source, growth habit, variety type, and marketable (mkt.) yield grown under organic conditions in Spring and Summer 2011 and 2012.

Entry	Source ^z	Growth habit	Type	Early total mkt.	Total mkt.	Fruit (no./acre) ^x	Avg fruit wt (oz) ^x
				yield ^y (lb/acre) ^x	yield ^y		
Abraham Lincoln	SESE	Indeterminate	Open-pollinated	4,861	10,023	71,148	4.7 ^w
BHN 602	Seedway	Determinate	F ₁ Hybrid	12,976	27,126	151,250	5.9
Celebrity	Harris Seed	Determinate	F ₁ Hybrid	17,939	33,574	205,216	5.9
Cherokee Purple	SESE	Indeterminate	Open-pollinated	6,810	10,382	46,706	8.4
Costoluto Fiorentino	Tomato Growers	Semideterminate	Open-pollinated	14,454	22,046	135,520	4.5
Crnkovic Yugoslavian	Seed Savers	Semideterminate	Open-pollinated	5,405	8,062	45,738	7.5
Druzba	SESE	Semideterminate	Open-pollinated	4,544	13,122	109,142	4.3
Fletcher 0377	Seedway	Determinate	F ₁ Hybrid	13,035	25,732	146,168	5.6
Florida Pink	Tomato Growers	Semideterminate	Open-pollinated	865	5,077	24,200	10.2
HMX 8847 F ₁	Harris Moran	Semideterminate	F ₁ Hybrid	7,346	14,567	103,818	5.3
HSX 8115H	Hortag	Semideterminate	F ₁ Hybrid	18,804	27,379	160,446	5.7
Jeff Davis	TomatoFest	Indeterminate	Open-pollinated	2,276	6,040	56,144	6.6
Mortgage Lifter VFN	SESE	Determinate	Open-pollinated	1,668	7,113	37,510	7.4
Mountain Fresh Plus	Seedway	Semideterminate	F ₁ Hybrid	13,049	28,064	146,410	5.8
Neptune	SESE	Indeterminate	Open-pollinated	6,037	15,436	132,132	3.0
Ozark Pink	SESE	Indeterminate	Open-pollinated	4,029	12,035	114,708	3.3
RFT 80771	Rogers/Syngenta	Semideterminate	F ₁ Hybrid	4,243	13,587	106,722	5.2
RFT 80772	Rogers/Syngenta	Semideterminate	F ₁ Hybrid	4,938	13,384	84,458	5.9
Scarlet Red	Harris Seed	Determinate	F ₁ Hybrid	8,361	19,733	146,168	5.1
Probabilities							
Variety				0.000	0.000		0.000
Year				0.000	0.002		
Variety × year				0.065	0.549		
Coefficient of variation				46%	30%		13%
LSD ($P \leq 0.05$) ^u				2,680	2,252		1.4

^zSeedway = Seedway Seed Co., Elizabethtown, PA; Harris Seed = Harris Seed Co., Rochester, NY; SESE = Southern Exposure Seed Exchange, Acorn Community, VA; Seed Savers = Seed Savers Exchange, Decorah, IA; TomatoFest = TomatoFest, Little River, CA; Rogers/Syngenta = Syngenta US, Greensboro, NC; Harris Moran = Harris Moran Seed Co., Modesto, CA; Hortag = Hortag Seed Co., Chapel Hill, NC.

^yEarly yield: 12, 21 July 2011; 5, 10, 13, 17 July 2012. Total yield: 12, 21, 26 July and 4, 11 Aug. 2011; 5, 10, 13, 17, 20, 24, 27 July and 2, 10 Aug. 2012.

^x1 lb/acre = 1.1209 kg·ha⁻¹, 1 oz = 28.3495 g, 1 fruit/acre = 2.4711 fruit/ha.

^wData for 2012 only.

^uFisher's protected least significant difference at $P \leq 0.05$.

produced 7000 lb/acre of large fruit, more than any other variety except BHN 602. The third highest yielding variety in 2011 was Fletcher 0377, which also had yield that was greater than all other varieties except BHN 602 and Mountain Fresh Plus.

In 2012, 'BHN 602' again had the highest total large yield compared with the other varieties with 11,869 lb/acre (Table 2). The next two entries with the highest total large yield in 2012 were 'Mountain Fresh Plus' and 'Florida Pink' with 6079 and 5543 lb/acre, respectively. These two entries had significantly higher total large yield compared with all the other entries with the exception of 'BHN 602'.

In 2012, 'Neptune' had no large fruit. Other entries with low total large yield in 2012 included 'Costoluto Fiorentino', 'Abraham Lincoln', 'Druzba', and 'Ozark Pink', all of which had less than 700 lb/acre.

Trial entries were also evaluated by variety type, F₁ hybrid or open-pollinated, and by growth habit (determinate, indeterminate, or semideterminate) (Tables 3 and 4). There was a significant variety type × year interaction for variety type, so results were evaluated separately for each year. In 2011, F₁ hybrids (13,025 lb/acre) out-yielded open-pollinated varieties (7200 lb/acre). In 2012, F₁ hybrids (32,119 lb/acre) outperformed open-pollinated varieties (15,226 lb/acre).

There were also significant differences between growth habits (Table 4). Determinate varieties yielded better with 26,846 lb/acre compared with indeterminate or semideterminate varieties. In addition, semideterminate entries with an average yield of 14,740 lb/acre yielded better than indeterminate entries with 9453 lb/acre.

Early yields can be an important characteristic in a variety because

earlier yields generally command higher prices. However, this may not be as important with tomato production for organic or local markets. Early yields were dominated by F₁ hybrid varieties. The exception to this was 'Costoluto Fiorentino', which is an open-pollinated variety. 'Costoluto Fiorentino' is described by the seed company as an heirloom variety from the Tuscany region of Italy. This variety is also described as an indeterminate variety; however, in this study, we scored it as semideterminate.

Other early entries were all F₁ hybrids. The company did not put HSX 8115H, an experimental hybrid from Hortag Seed (Chapel Hill, NC) forward as a commercial variety. 'Celebrity' is a popular F₁ hybrid used in commercial staked tomato production. The company, Harris Seed, describes this variety as semideterminate because although it has a determinate

Table 2. Tomato yield of early and total large fruit for each year in 2011 and 2012.

Entry	Early large yield ^a		Total large yield ^a	
	(lb/acre) ^y		(lb/acre)	
	2011	2012	2011	2012
Abraham Lincoln	173 ^x	255 ^x	269 ^x	255 ^x
BHN 602	3,071	8,197	8,082	11,869
Celebrity	716	2,386	1,675	3,107
Cherokee Purple	213	3,075	329	4,259
Costoluto Fiorentino	0	126	0	624
Crnkovic Yugoslavian	891	1,678	891	2,109
Druzba	0	0	0	81
Fletcher 0377	1,518	2,212	4,877	2,673
Florida Pink	0	834	0	5,543
HMX 8847 F ₁	126	2,215	439	3,148
HSX 8115H	1,280	1,199	1,845	1,199
Jeff Davis	63	2,241	263	3,753
Mortgage Lifter VFN	136	440	301	2,309
Mountain Fresh Plus	2,877	4,037	7,000	6,079
Neptune	499	0	833	0
Ozark Pink	126	77	736	77
RFT 80771	332	1,041	744	2,870
RFT 80772	1,184	661	1,457	2,939
Scarlet Red	2,212	1,028	2,643	2,218
Coefficient of variation	61%	54%	46%	45%
LSD ($P \leq 0.05$) ^w	446	785	791	1,057

^aEarly yield: 12, 21 July 2011; 5, 10, 13, 17 July 2012. Total yield: 12, 21, 26 July and 4, 11 Aug. 2011; 5, 10, 13, 17, 20, 24, 27 July and 2, 10 Aug. 2012.

^y1 lb/acre = 1.1209 kg·ha⁻¹.

^xGraded size: Large ≥ 2.5 inches (6.35 cm).

^wFisher's protected least significant difference at $P \leq 0.05$.

Table 3. Planned comparisons of variety type in an organic tomato trial with 19 entries in 2011 and 2012.

Type	2011	2012
	Total yield (lb/acre) ^a	
F ₁ hybrid	13,025	32,119
Open-pollinated	7,200	15,226
Probability		
Type	0.126	0.000
Year	0.002	
Type $\times$ year	0.037	

^a1 lb/acre = 1.1209 kg·ha⁻¹.

growth habit, it continues to produce fruit throughout the season. 'Mountain Fresh Plus' and 'Fletcher 0377' were two F₁ varieties with good early yield developed at North Carolina State University Mountain Horticultural Crops Research and Extension Center in Mills River, NC. According to the seed company, 'Mountain Fresh Plus' has resistance to fusarium wilt (*Fusarium oxysporum*) races 1 and 2, verticillium (*Verticillium albo-atrum*), and tolerance to nematodes (*Meloidogyne* sp.). 'Fletcher 0377' has resistance

to verticillium, nematodes, and tomato spotted wilt virus (TSWV).

Overall, high total yields were primarily with F₁ hybrid types, determinate or semideterminate varieties. Entries with high total yield included the previously mentioned varieties Celebrity, Mountain Fresh Plus, HSX 8115H, Fletcher 0377, and Costoluto Fiorentino. In addition, 'BHN 602' and 'Scarlet Red' had reasonably high yields. 'BHN 602', according to the seed company, was specifically developed for Florida growing conditions. It

Table 4. Planned comparisons of growth habit in an organic tomato trial with 19 entries, 2011–2012.

Growth habit	Combined years total yield (lb/acre) ^a
Determinate	26,846a ^y
Indeterminate	9,453c
Semideterminate	14,740b
Probability	
Growth habit	0.003
Year	0.002
Growth habit $\times$ year	0.818

^a1 lb/acre = 1.1209 kg·ha⁻¹.

^yYields followed by the same letter are not significantly different by Fisher's protected least significant difference at $P \leq 0.05$.

has resistance to fusarium wilt races 1, 2, and 3, verticillium wilt, and TSWV.

In both 2011 and 2012, F₁ hybrids outyielded open-pollinated varieties (Table 2). The F₁ hybrids were either determinate or semideterminate and the open-pollinated varieties were primarily indeterminate or semideterminate with only one determinate entry. The cultural practices of staked tomato on plastic mulch may have worked against the open-pollinated varieties because this type of production is specifically suited to determinate types. As the indeterminate tomato grew, it became more difficult to keep them trellised. If these plants had a more robust trellis system, they may have done better in terms of yield. The plants were not pruned, which affected trellising. It was felt that pruning the plants might bias the results. However, pruning is a cultural practice that is used with determinate types in staked tomato production. The indeterminate varieties, because of their growth habit, were not well supported late in the production season. In fact, in year 2 of the study, two severe thunderstorms caused some of the supporting stakes to collapse, which required additional stakes and string to support these plants. This resulted in additional work and difficulty harvesting these fruit. Indeterminate tomatoes are also known for their continued production once they reach maturity, unlike determinate tomato where they reach a set size, produce a flush of fruit and are finished. In year 1, fruit were harvested from 12 July to 11 Aug. and in

year 2 they were harvested from 5 July to 10 Aug. ≈ 4 and 5 weeks, respectively. This could have been extended for the indeterminate tomato, which can produce for a longer period (i.e., greenhouse production with indeterminate types); however, the total fruit yield is generally about the same on a per-plant basis.

All of the entries in the trial were red tomato varieties with the exception of Ozark Pink and Florida Pink, which were pink. According to the seed company, 'Ozark Pink' has resistance to fusarium wilt race 1, verticillium wilt, blossom end rot, and cracking. 'Florida Pink', although described by the seed company as a pink variety, did not have the same pink coloration of Ozark Pink. 'Florida Pink' had the largest fruit of all the entries in the trial with deep suture lines radiating from the stem end. 'Cherokee Purple', which is supposed to have a darker distinctive coloration that borders on brown, did not exhibit this trait in this trial. In fact, it had uneven color development with shoulders that remained green and fruit that never developed the darker color characteristic of this variety.

The average fruit of 5.8 oz, which was lower than the average for beefsteak tomatoes, may have been due to the lack of pruning. Along with controlling plant shape and facilitating trellising, pruning also results in large fruit.

Three F_1 hybrids that did not exhibit particularly high total yields included 'HMX 8847 F_1 ', 'RFT 80771', and 'RFT 80772'. 'HMX 8847 F_1 ' has been released as 'Red Bounty', and no additional information is available at this time concerning 'RFT 80771' and 'RFT 80772' other than they were experimental lines from Syngenta (Greensboro, NC). Many of the open-pollinated varieties have interesting backstories described in the seed catalogs. Some of these varieties date back to the 19th and early 20th centuries. 'Mortgage Lifter VFN', according to the seed company, dates back to the 1930s when it was developed in West Virginia from several large fruited tomatoes. 'Cherokee Purple' is dated pre-1890 with a Cherokee Indian origin. 'Abraham Lincoln' was introduced in 1923 as a late maturing variety. Along with 'Costoluto Fiorentino' from Tuscany, Italy, 'Druzba' was introduced from

Bulgaria and 'Crnkovic Yugoslavian' was introduced by Yasha Crnkovic from Vojvodina, Serbia.

The by-year interactions were generally an indication of the magnitude of yield differences with tomato yields better in year 2. There were some trends that were similar between the years even though the by-year interaction was significant. For example, both 'Mountain Fresh Plus' and 'BHN 602' had the greatest early large yield and total large yield in both years. There were notable exceptions to this, such as 'RFT 80772', which had early large yield of 1184 lb/acre in 2011 and 661 lb/acre in 2012. Other varieties that had lower early large yield in year 2 included Neptune, Ozark Pink, and Scarlet Red. By-year interaction differences that reflected only differences in magnitude were also evident in the comparison of F_1 hybrids and open-pollinated varieties for total yield.

In conclusion, the F_1 hybrid varieties did better than the open-pollinated varieties, which is not surprising since F_1 hybrids often exhibit hybrid vigor. Overall, the F_1 hybrids also had more uniform fruit. The open-pollinated varieties tended to have more fruit variation as would be expected. This is probably not an issue for retail-focused organic growers. Although not a focus of this study, disease resistance has been an important component in developing modern tomato varieties. This focus on disease resistance, as well as yield and fruit uniformity, has dramatically improved the tomato industry in the United States. Older open-pollinated varieties may offer interesting visual, textual, and flavor components that have not been the focus of modern breeding efforts. With the increase in the organic and local food markets, there may be areas in which plant breeding can focus to bring better disease resistance and yields to older varieties with unique characteristics. Combining the uniformity, high yields, and disease resistance of modern varieties with unique flavor, textual, and visual characteristics of older varieties could be the focus of new breeding efforts.

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