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2018 Fruit and Vegetable Crops Research Report

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Important Note to Readers

The majority of research reports in this volume do not include treatments with experimental pesticides. It should be understood that any experimental pesticide must first be labeled for the crop in question before it can be used by growers, regardless of how it might have been used in research trials. The most recent product label is the final authority concerning application rates, precautions, harvest intervals, and other relevant information. Contact your county's Cooperative Extension office if you need assistance in interpreting pesticide labels.

This is a progress report and may not reflect exactly the final outcome of ongoing projects. Please do not reproduce project reports for distribution without permission of the authors.

Cover: Summer squash grown at the University of Kentucky College of Agriculture, Food and Environment's Horticultural Research Farm in Lexington, Kentucky. **Photographer**: Steve Patton

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Contents

The 2018 Fruit and Vegetable Crops Research Program

John Strang, Horticulture

Fruit and vegetable production continues to show sustained growth in Kentucky. As the industry grows around a diverse collection of marketing tactics (wholesale, farmer markets, CSAs, and direct to restaurants) as well as various production systems, there continues to be a need for applied practical information to support the industry. The 2018 Fruit and Vegetable Crops Research Report includes results for 12 projects. This year fruit and vegetable research, demonstration plots were conducted in 8 counties in Kentucky: Clark, Gallatin, Knott, Marshal, McCracken, Metcalfe, Shelby and Todd. Research was conducted by faculty and staff from the Horticulture, Entomology and Plant Pathology Departments in the University of Kentucky College of Agriculture, Food and Environment. Faculty and staff of Kentucky State University also contributed to this report.

Variety trials included in this year's publication include carrots, bell peppers, blackberries, broccoli, haskap berries and summer squash. Additional research trials include evaluation of assorted bags for insect and disease control in apple, rootstock effects on apple tree growth and yield, an investigation of the impact of three Alltech formulations on two soil enzymes, hot pepper plant size, and fruit composition, growing eggplant in Biochar and animal manure amended soil, and a study of phenolic content of fruit and leaves of interspecific hybrid tomatoes. Evaluation of varieties is a continuing necessity and allows us to provide the most up to date information in communications with vegetable growers. The vegetable variety trial results are the basis for updating the recommendations in our Vegetable Production Guide for Commercial Growers (ID-36). These updates are not based solely on one season's data or location. It is necessary to trial varieties in multiple seasons and if at all possible, multiple locations. We may also collaborate with researchers in surrounding states such as Ohio, Indiana, and Tennessee to discuss results of variety trials they have conducted. The results presented in this publication often reflect a single year of data at a limited number of locations. Although some varieties perform well across Kentucky year after year, others may not. Following are some helpful guidelines for interpreting the results of fruit and vegetable variety trials.

Our Yields vs. Your Yields

Yields reported in variety trial results are extrapolated from small plots. Depending on the crop, individual plots range from 1 to 200 plants. Our yields are calculated by multiplying the yields in these small plots by correction factors to estimate per-acre yield. For example, if you can plant 4,200 tomato plants per acre (assuming 18" within row spacing) and our trials only have 10 plants per plot, we must multiply our average plot yields by a factor of 420 to calculate per-acre yields. Thus, small errors can be greatly amplified. Due to the availability of labor, research plots may be harvested more often than would be economically possible. Keep this in mind when reviewing the research papers in this publication.

Statistics

Often yield or quality data will be presented in tables followed by a series of letters (a, ab, bc, etc.). These letters indicate whether the yields of the varieties are statistically different. Two varieties may have average yields that are numerically different, but statistically are the same. For example, if Tomato Variety 1 has an average yield of 2,000 boxes per acre, and Variety 2 yields 2,300 boxes per acre, one would assume that Variety 2 had a greater yield. However, just because the two varieties had different average yields does not mean that they are statistically or significantly different. In the tomato example, Variety 1 may have consisted of four plots with yields of 1,800; 1,900; 2,200; and 2,100 boxes per acre. The average yield would then be 2,000 boxes per acre. Tomato Variety 2 may have had four plots with yields of 1,700; 2,500; 2,800; and 2,200 boxes per acre. The four plots together would average 2,300 boxes per acre. The tomato varieties have plots with yield averages that overlap, and therefore would not be considered statistically different, even though the average per acre yields for the two varieties appear to be quite different. This example also demonstrates variability. Good varieties are those that not only yield well but have little variation. Tomato Variety 2 may have had yields similar to variety 1 but also much greater variation. Therefore, all other things being equal, tomato variety 1 may be a better choice due to less variation in the field.

Statistical significance is shown in tables by the letters that follow a given number. For example, when two varieties have yields followed by completely different letters, they are significantly different; however, if they share even one letter, statistically they are no different. Thus a variety with a yield that is followed by the letters "bcd" would be no different than a variety followed by the letters "cdef," because the letters "c" and "d" are shared by the two varieties. Yield data followed by the letters "abc" would be different from yield data followed by "efg."

When determining statistical significance, we typically use a P value of 0.05. In this case, P stands for probability. If two varieties are said to be different at $P < 0.05$, then at least 95 percent of the time those varieties will be different. If the P value is 0.01, then 99 percent of the time those varieties will be different. Different P values can be used, but typically $P < 0.05$ is considered standard practice for agricultural research.

This approach may be confusing, but without statistics our results wouldn't be useful. Using statistics ensures that we can make more accurate recommendations for farmers in Kentucky.

Erect Thornless Blackberry Cultivar Trial

Dwight Wolfe and Ginny Travis, Horticulture

Introduction

Blackberries are an important small fruit crop in Kentucky. Demand for this fruit at farmers' markets is strong and generally exceeds supply. Producers are looking for better cultivars that are thornless, productive and have berries with good size and flavor. Resistance to orange rust and rosette are also a consideration among growers. Three thornless erect cultivars (Natchez, Osage, and Ouachita) and two selections (A-2434T and A-2491T), all from John Clark's breeding program at the University of Arkansas, were evaluated at the UKREC, Princeton, Kentucky, from 2013 through 2018. Results have been reported annually, and this is the final report on this trial.

Materials and Methods

Twenty plants each of five cultivars, Natchez, Osage, Ouachita, and two numbered selections, A-2491T and A-2434T were planted in the spring of 2013. One cultivar was allocated to each plot and each of the four rows in this trial contained five plots per row. Plants were spaced 2.5 feet apart within 12.5-foot long plots in rows spaced 18 feet between rows. Cultivars were randomized in a randomized block design with each row being one block. Trickle irrigation was installed, and plants were maintained according to local recommendations. Fruit in 2018 was harvested from one to three times per week as needed from June 19 through July 9. Yield and number of fruit picked were recorded. Fruit size was calculated as the average weight (yield divided by the number of berries picked) for each plot.

Results and Discussion

Yields averaged from just 1.6 lbs. per 5-plant plot for A-2491 to over 14 lbs. per plot for Osage (Table 1). Yields varied significantly among cultivars in 2018 (Table 1), with Osage being significantly more productive than all other cultivars. But yields were much lower than last year for all cultivars and yields in 2017 were

Table 1. Summary of 2018 results from the blackberry cultivar trial at UKREC, Princeton, KY.

Cultivar	Yield (lb/plot)[1]	Weight (g/berry)[2]	Percent Yield: 1st week of harvest	2nd week of harvest	3rd week of harvest	4th week of harvest
Osage	14.8 (22.7)	3.4	21.5	28.7	41.4	8.4
A-2434-T	4.4 (15.8)	4.3	54.8	15.6	21.7	7.9
Ouachita	2.6 (14.8)	3.2	30.9	16.4	34.6	18.1
Natchez	4.5 (9.0)	4.0	38.1	24.7	31.8	5.4
A-2491-T	1.6 (8.5)	2.2	37.9	38.3	23.8	0.0
LSD(0.05)[3]	4.4 (7.0)	0.7	23.5	8.9	18.9	5.8

[1] 2017 yields in parentheses.
[2] Fruit weight was calculated as the average weight (yield divided by the number of berries picked) for each plot.
[3] Least significant difference at 0.05 probability level. Differences between two numbers within a column that are less than the least significant difference are not significantly different from one another at the 0.05 probability level.

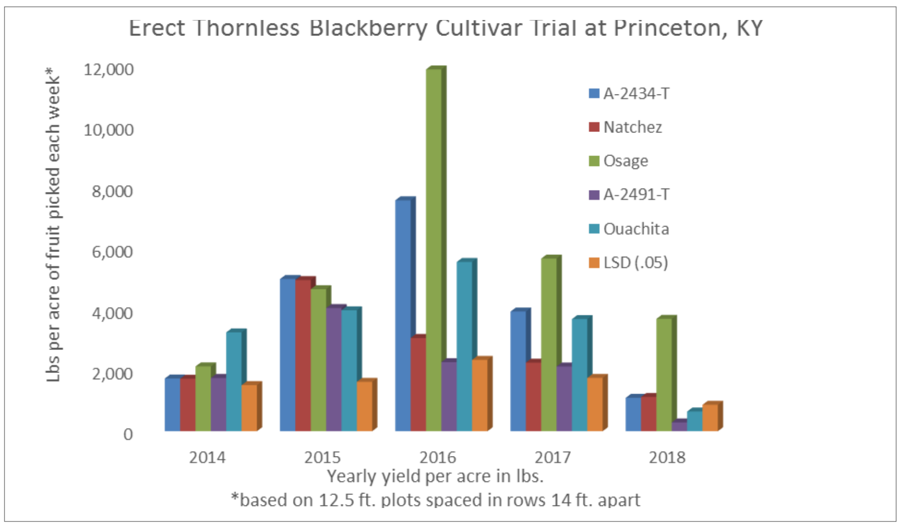

Figure 1. Yields (lb.) per acre from 2014 through 2018 from the erect thornless blackberry cultivar trial established in 2013 at UKREC, Princeton, KY.

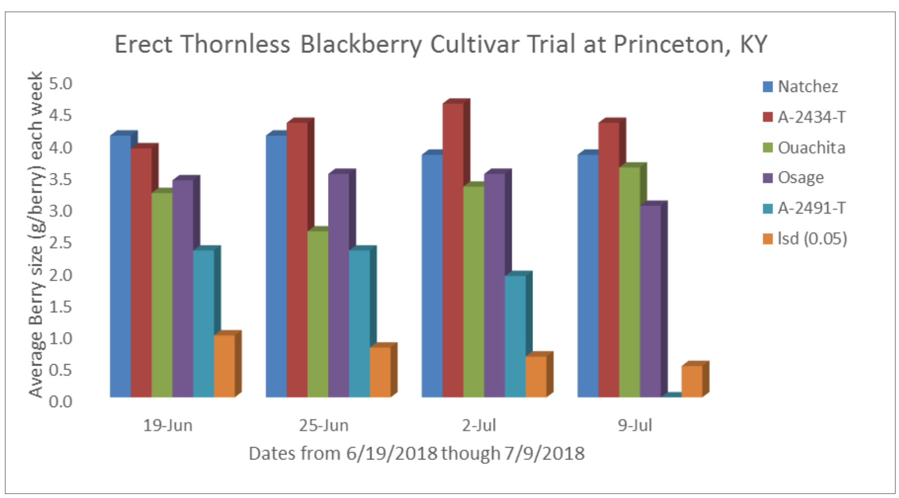

Figure 2. Berry size (as measured by average weight per berry) in 2018 for erect thornless blackberry cultivars.

much lower than in 2016 (Figure 1). Some plants might have been overcropped or stressed in previous years due to injury at the base of the floricanes and depleted most plant reserves to produce the fruit, but cane blight and a decline in yield were observed in this trial in 2017 and may have been the cause of the low yields of some of less productive cultivars in 2016. This disease grew worse in 2018 along with the further decline in yield of all cultivars as in 2017. Osage was statistically more productive than all other cultivar from 2016 through 2018, despite the declining yields (Figure 1).

A-2434-T, and Natchez (Table 1) had significantly larger berries than Ouachita and A-2491-T in 2018. However, berry size (as measured by weight per berry) of Osage was statistically smaller than that of A-2434-T but not Ouachita. Berry size remained fairly constant throughout the season for Osage, but was more variable for the other cultivars (Figure 2). The amount of fruit remaining on A-2491-T plants after the third week of picking was negligible. Consequently, berry size went to zero on the bar chart.

Berry size increased from 2014 to 2015 but was smaller for all cultivars from 2016 through 2018 (Figure 3), possibly due to the increasing severity of cane blight over that three-year period. Natchez and the selection A-2434-T had the largest berries each year while the selection A-2491-T had the smallest berries each year except in 2017.

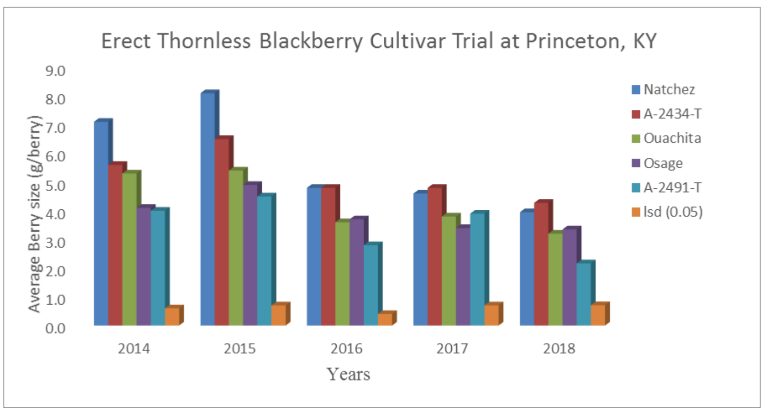

Figure 3. Average berry size for each year from 2014 through 2018 from the erect thornless blackberry cultivar trial at UKREC, Princeton, KY.

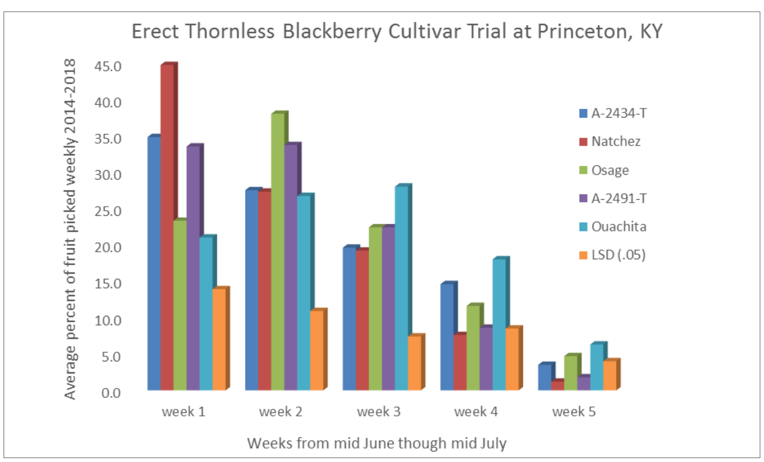

Figure 4. Average percent of fruit harvested weekly over five-year period 2014-18.

The percent of fruit ripening for each cultivar varied significantly for each week fruit was harvested in 2018 (Table 1). Ouachita significantly lagged the other cultivars in ripening as seen in the percent of fruit that ripened during the last week of picking (Table 1). Averaged over the five years from 2014 through 2018, all berries in this trial ripened over about a four to five-week period from about mid-June through about mid-July (Figure 4). Natchez and A-2434-T tended to peak during the first week of the season and were the first to ripen. This was followed by A-2491-T, which tended to peak between the first and second week of picking, and Osage and Ouachita, which tended to peak during the second and third week of picking, respectively.

Data on taste was not collected in 2016 or 2018, but was in 2014, 2015, and 2017. In 2014, Natchez ranked significantly but only slightly lower in taste than Osage and A-2491-T. From 2015 through 2017, all cultivars have rated from good to excellent with no significant differences between cultivars being detected. Casual comments regarding taste in 2018 were that berries from all cultivars tended to have a bitter taste and/or were not very sweet. This may be related to dilution of sugars from above normal rainfall and heavy cloud cover that reduced sugar production this season.

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Performance of Three Primocane-fruiting Blackberry Selections Grown Organically at Kentucky State University

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Introduction

In Kentucky, over 670 farms grow berry crops, including 368 farms that grow blackberries, which are valued at over $2,600,000 annually (Census of Agriculture, 2012). Blackberries are native to Kentucky and Kentucky's climate is well-suited for blackberry production. Two cane types exist within brambles: primocanes (or first-year canes), which are usually vegetative, and floricanes, which are the same canes that flower and produce fruit the next growing season. Primocane-fruiting blackberries, also known as fall-fruiting and ever-bearing blackberries, have the potential to produce two crops per year, with a normal summer crop (floricane) and a later crop on the current season's primocanes. Primocanes flower and fruit from mid-summer until frost, depending on temperature, plant health, and the location in which they are grown. Growers can reduce pruning costs by mowing canes in late winter/early spring to obtain a primocane crop only; this also provides anthracnose, cane blight, and red-necked cane borer control without pesticides. Relying only on a primocane crop also avoids potential winter injury of floricanes. However, later ripening blackberries are more prone to spotted wing drosophila infestations and growers that are marketing the berries will need to maintain a spray program.

The first commercially available primocane-fruiting blackberry varieties, 'Prime-Jim®' and 'Prime-Jan®', were released by the University of Arkansas in 2004. 'Black MagicTM' is a thorny, primocane-fruiting selection suited for home growers and on-farm sales (Clark et al., 2014). 'Prime-Ark®45,' released in 2009 for commercial use, has improved heat tolerance and shipping traits compared to previous selections. 'Prime-Ark® Freedom' was the first thornless primocane-fruiting blackberry and produces large fruit, but displays inferior shipping traits compared to 'Prime-Ark® 45.' 'Prime-Ark® Traveler,' also a thornless primocane-fruiting selection, has improved storage and shipping characteristics compared to 'Prime-Ark® Freedom' and is recommended for commercial production. In the fall of 2017, APF-205T was released as 'Stark® Black Gem®.' APF-268 is an advanced selection from the University of Arkansas breeding program. It is a primocane-fruiting blackberry that is not thornless, but has a reduced number of thorns compared to other thorny primocane-fruiting cultivars.

Summer temperatures above 85°F can greatly reduce fruit set, size, and quality on primocanes, which results in substantial reductions in yield and fruit quality (Clark et al., 2005; Stanton et al., 2007). The objective of this study was to determine if 'Prime-Ark® Traveler' is superior to 'Stark® Black Gem®' and the advanced selection APF-268 in terms of yield and fruit quality under Kentucky growing conditions. Here we report results from the trial in its first and second year of fruit production.

Materials and Methods

In May 2016, a primocane-bearing blackberry trial was planted at the KSU Research and Demonstration Farm on certified organic land. The planting contained the selections 'Prime-Ark® Traveler,' 'Stark® Black Gem®,' and APF-268, which are all primocane-fruiting selections from the University of Arkansas. Plants were arranged in a completely randomized design, with four replicate plots each containing five plants of 'Prime-Ark® Traveler,' 'Stark® Black Gem®,' or APF-268 (total of 20 plants of each selection) in 10-foot plots with a plant spacing of 2 feet. This trial was managed with organic practices following the National Organic Program standards. A combination of cultivation, hand weeding, and straw mulch was used for weed control. Drip irrigation was used as needed. Plots were fertilized with Nature Safe 10-2-8 fertilizer (Griffin Industries LLC, Cold Spring, KY) at 100 lb. of N per acre. Primocanes were tipped on all selections at one meter beginning in early June to promote lateral branching and flowering. Ripe fruit were harvested twice a week, from late June through mid-October. Analysis of variance and least significant difference means separation were performed using CoStat Statistical Software (CoHort Software, Monterey, CA).

Results and Discussion

Fruit were harvested from late July until mid-October. A floricane crop was produced in 2017; however, due to cold temperatures during the winter of 2017-2018, only a primocane crop was produced in 2018. The results presented here are primocane crops for 2017 and 2018. Growing conditions in 2017 and 2018 were hot; daily high temperature was above 85°F for 49 out of 122 days from June through September in 2017 and 59 out of 122 days in 2018. The average high for July was 84.9°F in 2017 and 84.7°F in 2018. The high temperatures may have reduced fruit set, size, and quality on primocanes, especially in 2018.

In 2017, fruit size varied significantly; 'Stark® Black Gem®' and APF-268 had a larger fruit size (4.8 g for both) versus 'Prime-Ark® Traveler' (3.4 g). APF-268 had significantly higher

Table 1. 2017-18 yields and berry weights for 'Prime-Ark® Traveler', 'Stark® Black Gem®', and APF-268 at the Kentucky State University Harold R. Benson Research and Demonstration Farm, Frankfort, KY.

	2017		2018	
Selection	**Fruit Weight (g)**	**Yield (lb/acre)**	**Fruit Weight (g)**	**Yield (lb/acre)**
'Stark® Black Gem®'	4.82 a1	1745 b	4.24 a	860 a
'Prime-Ark® Traveler'	3.42 b	1274 c	3.26 b	757 a
APF-268	4.83 a	2420 a	4.36 a	961 a

1 Numbers in a column followed by the same letter are not significantly different (least significant difference P = 0.05).

primocane yield (2420 lb/acre) whereas 'Prime-Ark® Traveler' had the lowest yield (1,274 lb/acre) and 'Stark® Black Gem®' was between the two (Table 1). In 2018, a similar trend was seen in fruit size for the selections. APF-268 and 'Stark® Black Gem®' had significantly larger fruit sizes (4.4 g and 4.2 g) compared to 'Prime-Ark® Traveler' (3.3 g) (Table 1). In contrast to yields in 2017, there was no significant difference in yield in 2018. Primocane yields in 2018 were approximately half of what they were in 2017, possibly due to the greater number of days at elevated temperatures in the summer of 2018.

The University of Arkansas Blackberry Breeding Program recommends that commercial producers plant 'Prime-Ark® Traveler' due to its superior shipping and storage qualities. Due to softer fruit, 'Stark® Black Gem®' is recommended for pick-your-own (also called U-pick) and on-farm sales as well as for home gardens. Year-to-year yield characteristics will need to be evaluated further; however, the data to date suggests that 'Stark® Black Gem®' has large fruit, yields well in Kentucky, and should be considered by growers interested in producing primocane-fruiting blackberries for markets with little to no shipping.

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Haskap Selection and Variety Evaluation

John Strang, Chris Smigell, and John Snyder, Horticulture

Haskap (*Lonicera caerulea* subspecies *emphyllocalyx*) is a blue honeysuckle subspecies. Haskaps are native to Canada and the northern islands of Japan where it is popular both fresh and in baked goods, juices, ice cream, candies and wine. Haskaps differ from the Honeyberries (*Lonicera kamchatika* subspecies *kamtshatica, edulis, boczkarnikovae* and altaica - native to Russia, North Korea and the Czech Republic) in that haskaps are adapted to more moderate climates and bloom later. Even so, they bloom during April in Kentucky when frosts are prevalent. Flowers have been reported to be hardy to 17°F.

Furthermore, they are not well adapted to high summer temperatures and a long growing season. Plants cease growth shortly after fruiting and then leaf bronzing occurs. It has been suggested that sunburn and/or high temperature exposure causes this, as no diseases have been associated with the problem. Varieties vary in the amount and timing of leaf bronzing and American varieties have some resistance to this.

We are evaluating haskaps as a potential crop for Kentucky growers since they have very high antioxidant levels and ripen early with strawberries, and thus do not need insecticide sprays to control spotted wing drosophila. The crop has been reported to have few insect and disease pests other than powdery mildew and thus has potential for organic production.

Haskap plants provided by Gardens Alive! Inc. (Lawrenceburg, IN) were planted at the University of Kentucky Horticultural Research Farm in Lexington to evaluate their adaptation and production potential. Very few fruit were produced in 2015, the second growing season, and no yield data were collected. Yields and data for the 2016 and 2017 growing seasons were reported in the 2016 and 2017 Fruit and Vegetable Research Reports, respectively. This report contains plant development and leaf bronzing evaluations as well as yield and fruit quality results for the 2018 season. This will be the final report for this study as almost half of the plants have died.

Materials and Methods

Ten potted, leafed-out Haskap selections and the variety 'Borealis' were moved from a greenhouse and transplanted on 2 June 2014 into a well-drained Maury silt loam at the University of Kentucky Horticultural Research Farm, Lexington, KY. Plants were set 6 feet apart in rows with 12 feet between rows. Individual plant plots were replicated six times in a randomized block design. Six-foot wide DeWitt Sunbelt Weed Barrier was cut to fit around the plants and stapled to the ground with SSS8 8-inch long, 8 gauge heavy duty staples for weed control down the row. Hard plastic, ¾-inch drip irrigation tubing was installed on top of the landscape fabric down each replication row and a one-gallon per hour emitter was inserted 6 inches from the base of each plant. Irrigation was provided as needed.

No insecticides, fungicides or herbicides were used on the planting. Plants were only fertilized in April 2016 and 2018 with one cup of Nature Safe 10-2-8 (Darling Ingredients, Irving TX). Bird netting was erected over each row prior to berry ripening, resting on wires attached to T-shaped supports and anchored to the ground with wire staples.

Frost injury, plant bloom density and floral development data were collected in spring, 2017. Fruit were harvested and weighed on four dates. Twenty berries were weighed at the first three harvests to determine average berry weight. Berry appearance, firmness, sweetness, flavor, and flower petal adherence to the fruit were also assessed three times for each plant. Percentage of leaf bronzing over the whole plant was estimated and calculated as the area under the disease progress curve (AUDPC) five times in 2018 and plant height and width were measured on 9 September 2018. Plant mortality was assessed on 30 September 2018.

Table 1. Haskap yields and fruit characteristics.

Selection/ variety	Yield/ plant[1] (oz)		Wt 20 berries[1,2] (oz)		Attractive-ness[3] (1-5)	Firmness (1-5)[4]	Sweetness (1-5)[5]	Flavor (1-5)[6]	Adhering flower petals (1-5)[7]
85-19	52.8	a	0.46	e	3.8	3.1	3	3.3	1.1
44-19	33.4	a	0.57	cde	3.6	2.8	2.7	3.2	1.4
85-28	31.8	a	0.69	bcd	3.3	2.8	2.8	3	2.3
21-20	26.4	a	0.52	de	3.8	2.1	3.1	3.5	1.6
85-35	25.4	a	0.73	abc	3.5	3	3	3.8	1
84-105	24	a	0.57	cde	4	2.5	3	3.8	1.5
46-55	20	a	0.88	a	3	2.5	3.7	4.2	2
'Early Blue' 51-02	18.1	a	0.66	bcd	3.3	2.3	3.7	4	1
56-51	14.4	a	0.82	ab	3.1	2.6	2.7	3.1	1.8
'Sunrise' (29-55)	13.6	a	0.54	de	3.2	2.6	4.3	3.8	1.2
'Borealis'	6.2	a	0.54	de	2.8	2.5	3.3	3.3	1.5

1 Numbers followed by the same letter are not significantly different (Duncan Multiple Range Test LSD *P*≤0.05).
2 Average weight based on 20 berries at first 3 harvests.
3 Attractiveness: 1 = poor, 5 = excellent.
4 Firmness: 1 = soft, 5 = very firm.
5 Sweetness based on two evaluations: 1 = tart, 5 = sweet.
6 Flavor: 1 = poor; 5 = excellent.
7 Flower petals adhering to fruit: 1 = none; 5 = many.

Table 2. Haskap plant survival, size, percent bloom, foliar frost injury and leaf bronzing.

Selection/ variety	Plant mortality[1] (% dead)	Plant Volume[2] (cu ft)	Bloom 2018[3,4] (%)		Foliar frost injury 2018[4,5] (%)		Leaf bronzing 2016[4] (AUDPC)[6]		Leaf bronzing 2017[4] (AUDPC)[6]		Leaf bronzing 2018[4] (AUDPC)[6]	
85-19	33	43.8	92	a	5.6	bc	2081	cd	1459	c	1029	c
44-19	33	14.6	98	a	19	b	2650	a-d	3101	a	3163	ab
85-28	66	32.2	88	ab	1	c	2473	bcd	1952	c	1853	bc
21-20	50	34.5	70	bc	7	bc	4550	a	2853	bc	2918	ab
85-35	83	23.6	100	a	0	c	944	ef	1657	c	2854	abc
84-105	83	16.5	-		0	c	3278	abc	931	c	931	c
46-55	66	16.5	47	de	8	bc	3897	ab	3009	a	3778	a
'Early Blue' (51-02)	0	27	58	cd	5	bc	1479	cd	2166	bc	1700	c
56-51	50	23.8	37	e	47	a	3366	abc	3557	a	3848	a
'Sunrise' (29-55)	0	8.7	68	c	6	bc	1877	cd	1586	c	1966	bc
'Borealis'	66	3.8	35	e	0	c	3432	abc	3654	a	3196	ab

1 Assessed on 30 September 2018.
2 Calculated as volume of a cylinder based on plant height and width.
3 Visual estimate of percent bloom on 18 April 2018. Bloom was delayed on 84-105 and it was too early to rate this selection.
4 Means within same column followed by the same letter are not significantly different (Duncan's Multiple Range Test LSD *P*≤0.05).
5 Visual estimate on 22 April 2018 of percent leaf injury following freezes down to 20.7 °F on 14 March and 26 °F on 5 April 2018.
6 The area under the disease progress curve (AUDPC) is a quantitative summary of disease intensity over time, calculated from leaf bronzing and drop ratings taken on 18 July, 11 August, 2 and 15 September, and 11 October 2016; 23 August, 11 and 22 September, and 7 October 2017; and 1, 16, and 31 August, 16, and 30 September 2018. Higher numbers in the columns indicate greater cumulative leaf bronzing and leaf drop.

Results and Discussion

The 2018 season was very warm early in the season and cooler later, with more rainfall than normal. Fruit were harvested on 16, 24, 31 May and 4 June. Harvest began 8 days later than it did in 2017. Fruit yield and berry characteristics are shown in Table 1. Selections are ranked based on yield-per-plant.

Overall, **85-19** was the superior selection this season, as in 2016 and 2017. It tended to have the highest yield, although there was no statistical difference in yield between it and any of the other selections and 'Borealis.' This was primarily due to excessive trial plant mortality and the resultant lack of data. Selection 85-19 had an attractive, small-sized, firm fruit. However, it did not rank highly in flavor or sweetness. It also had few flower petals that adhered to the fruit after harvest and the fruit dropped easily from the plant at maturity when the plant was jostled (Table 3). Selection 85-19 had a relatively low plant mortality (Table 2) in that two of its total of six plants died. Return bloom was excellent and spring foliar frost injury was minimal. This selection tended to have the largest plants and some of the lower leaf bronzing ratings for 2016, 2017, and 2018 in late summer. Selection 85-35 also had very attractive fruit with few adhering flower parts after harvest. It had larger and slightly better-tasting fruit than 85-19. Both had similar firmness and sweetness ratings. For both selections, berry skins were firm and fruits had a uniform shape. However, yield was half that of 85-19, plant size was smaller, and plant mortality was excessive with an upward trend from 33 percent mortality in 2017 to 83 percent in 2018. Floral development for both selections in 2018 (Figure 1) as in 2017 was slightly slower than for several other selections and 'Borealis,' which indicates that the blooms of these two selections might be a little less susceptible to spring frost injury. Both also were rated as having very high levels of return bloom (Table 2).

'Borealis,' the standard variety in the trial, has not performed as well as most of the other selections. Yields have been low and plants have been very small, although no foliar frost injury was noted in 2018. 'Borealis' was one of the better-yielding, larger-fruited haskap varieties in Canada at the time that this trial was planted. 'Borealis' fruit were rated slightly higher for sweetness and flavor than were 85-19 and 85-35. 'Borealis' has had a higher leaf bronzing rating, although it has been reported to have little leaf sunburn or bronzing in Canada. Four 'Borealis' plants (66 percent) have died in the trial.

Varieties and selections that show potential are:

- 44-19, which yielded well, had firm, medium-sized fruit, but had smaller plants and a lower sweetness and flavor rating
- 'Early Blue' (51-02), has 100 percent plant survival, moderate plant size, and a low leaf bronzing tendency. It has a relatively low yield, very sweet, good-flavored, but softer fruit.
- 46-55 has had a 66 percent plant loss at this point, with a moderate yield and a few more flower parts adhering to the fruit. It has tended to have the largest berry size, high sweetness and flavor ratings, but was less attractive. Yield was moderate.
- 'Sunrise' (29-55), has 100 percent plant survival, small plants and low leaf bronzing levels. It appears to be slightly ahead of other trial selections in floral development (Figure 1), but had relatively low foliar frost injury levels. The fruit was fairly attractive, had the highest sweetness and flavor ratings and moderate fruit firmness. Yields have been very low.

Evaluation of harvest dates (data not shown) shows that all selections produced fruit over about a three-week period, (16 May through 4 June, 2018). 'Borealis' produced most of its fruit early, on 16 May. 'Sunrise' (29-55) and 'Early Blue' (51-02) were harvested from early to mid-season. The 21-20, 44-19, 46-55, 56-51, 85-19 and 85-28 ripened in mid-season, and 84-105 and 85-35 ripened mostly at the end of the harvest period. Selection 21-20 ripened mostly in mid-season, but some fruit was also harvested on the earliest and latest harvest dates. It is interesting that these data correspond well with Figure 1 in that the floral development for 'Borealis,' 'Sunrise' (29-55), and 'Early Blue' (51-02) tended to be the earliest of all the selections and these fruit were the earliest to mature and 84-105 was the slowest to develop in the spring and ripened most of its fruit late.

Table 3. Haskap selection/variety fruit observations.

Selection/ variety	Fruit observations
85-19	Long, slender, uniform berry size and shape; attractive wax bloom; easy to pick since fruit is on bush exterior; fruit shakes off easily; some adhering leaves and stems
44-19	Uniform berry size and shape; heavy wax bloom; tart when ripe; many adhering leaves and stems; a few conjoined1 berries; fruit shakes off easily sometimes
85-28	Variable fruit size and shape; fruit darker in color than other selections; a few adhering stems
21-20	Uniform fruit size and almond shape; heavy wax bloom; only selection with a fruity taste; persistent stems; fruit does not shake off or release from bush easily; fruit skin may slip off during harvest when pulled
85-35	Uniform fruit size and shape; attractive, firm skin that holds up well; no conjoined fruit; fruit shake from plant easily
84-105	Uniform fruit size and shape; heavy wax bloom
46-55	Uniform berry shape, darker fruit color; soft when ripe, great flavor; a number of conjoined fruit; adhering stems; easy to pick; fruit don't shake off easily
'Early Blue' (51-02)	Irregular fruit size and shape; lumpy fruit; heavy wax bloom; no conjoined fruit; close to blueberry in taste; easy to pick and fruit shake from plant easily; most fruit hang near base of bush
56-51	Variable berry size and chick pea shape; heavy wax bloom; a few conjoined berries; easy to pick but fruit do not shake from bush easily; many fruit hang near base of bush
'Sunrise' (29-55)	Variable sized, odd-shaped fruit with a lumpy surface; heavy wax bloom; sweet fruit; few conjoined berries; easy to pick and fruit shake from plant easily
'Borealis'	Irregular shaped berries; some conjoined fruit; many adhering stems

[1] Conjoined berries are open on one side exposing the two fruitlets, as opposed to most berries where the two fruitlets are completely enclosed in a blue sack forming a single berry.

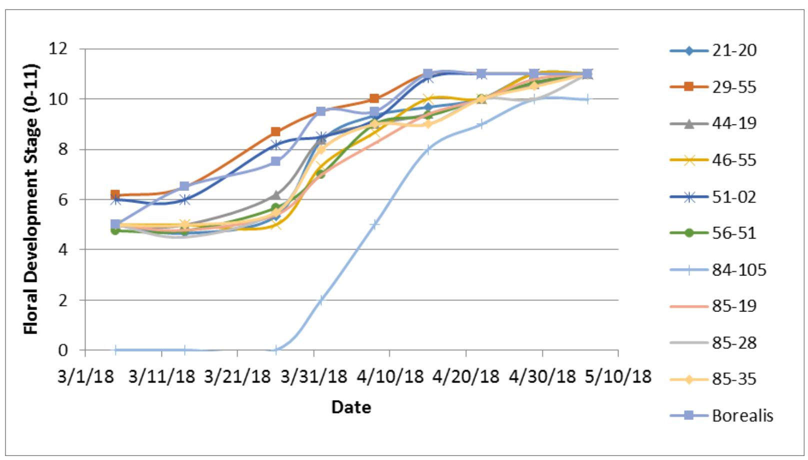

Figure 1. Selection/variety floral developmental stage by date. Floral development stages: 1 = buds dormant, 2 = buds showing green, 3 = ¼" green, 4 = ½" green, 5 = flower buds visible, 6 = first bloom, 7 = 25% bloom, 8 = 50% bloom, 9 = 75% bloom, 10 = full bloom, 11 = small fruit.

Selections 21-20, 84-105, 56-51, and 85-28 performed less desirably again and all had relatively high numbers of dried flower petals that adhered to the fruit. These would not be attractive if marketed fresh, and may not be useable in processed products that use the entire fruit.

Japanese beetles caused some minor leaf feeding damage in 2018. All dead plants were taken to the University of Kentucky Plant Diagnostic Lab and were diagnosed with Phytophthora root rot based on an ELISA test procedure. Phytophthora root rot has not been mentioned as a problem in growing haskaps previously. No powdery mildew has been detected in the planting.

Acknowledgments

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Evaluation of Assorted Bags for Insect and Disease Control in Apple 2018

Nicole Gauthier, Plant Pathology, and Ric Bessin, Entomology

Introduction

Fruit bagging is a technique that physically protects fruit from pests. It is common in Japan for production of gourmet apples. It has also been used by organic growers, small fruit growers, and backyard orchardists who wish to reduce pesticide applications during the growing season. The practice has also been adopted for other fruits such as grape and peach. Previous research has confirmed the efficacy of Japanese fruit bags (also called oriental fruit bags) for management of late-season pests, stink bugs and codling moths. This project expanded the range of bag types and the damage by a range of pests to better understand potential for bagging in Kentucky orchards.

Materials and Methods

Three trees each of two cultivars were selected for demonstration. 'Gala' represented early/mid-season harvest; bags would remain on trees for approximately 12 weeks. 'Fuji' represented mid/late-season harvest; bags would remain on trees for approximately 20 weeks. Ten fruit were selected per treatment/bag type per tree. Early season fungicides and insecticides were applied according to University of Kentucky recommendations (ID-232: Midwest Fruit Pest Management Guide, 2018). A final insecticide spray was applied one week prior to bagging.

Four types of bags were used for the experiment (Table 1) and applied on 4 June when fruit were approximately 0.5 inch to 0.75 inch (1.3 cm to 1.9 cm) in diameter. Bi-layer Oriental/Japanese fruit bags (Table 1) were used according to directions and secured around fruit stems (pedicels) using the embedded wire. Paper lunch bags were cut to 5 inch to 6 inches long with a 2.5 inch slit down one side; fruit stems were slipped through this slit and twist ties were used to secure the pleated bag. Clemson bags (Table 1) were used according to directions; the branch of the tree was aligned between slits, and the bag was secured around the spur bearing the fruit with the embedded wire. Plastic freezer bags (Table 1) were "zipped" up to the fruit stems and further secured with staples; corners were cut from the bottoms of bags for condensation drainage.

Table 1. Treatments (bags), source, and approximate costs.

Treatment/ Bag Name	Bag Description	Source	Approx. cost/bag
Oriental, Japanese	double layer paper/wax paper	Wilson Orchard and Vineyard Supply	$0.35
Clemson	single layer paper	Clemson University	$0.10
Lunch	white paper lunch bag	Good Value brand, Walmart	$0.05
Zip	plastic freezer bag	Ziploc brand, Walmart	$0.10

'Gala' and 'Fuji' fruit were harvested on 20 Aug and 10 Oct, respectively. Bags were left on fruit until harvest. Each fruit was rated for bag retention, as well as for a range of insect and disease damage. Results were analyzed using Fisher's LSD.

Results and Discussion

Bag retention (Fig 1). There was no significant difference in bag retention in the 'Gala' (Aug) plots, but retention was significantly lower in the lunch bag treatment in the 'Fuji' (Oct) plots.

Stink bugs (Fig 2). There was a significantly lower percentage of stink bug damaged fruit in the Oriental fruit bag treatment in the 'Fuji' (Oct) plot compared to other bag types.

Coddling moth (Fig 2). All bag treatments had significantly lower incidence of codling moth than non-bagged treatments in both 'Gala' (Aug) and 'Fuji' (Oct) plots.

Sooty blotch/fly speck (Fig 3). There was significantly less flyspeck incidence with Oriental fruit bags in the 'Gala' (Aug) plots. There was significantly less sooty blotch and flyspeck incidence with Oriental fruit bags and the non-bagged control in both the 'Gala' (Aug) and 'Fuji' (Oct) plots.

Fruit rots. There was significantly less bitter rot in all treatment/bag types compared to the non-bagged control in both 'Gala' (Aug) and 'Fuji' (Oct) plots. There were signifi-

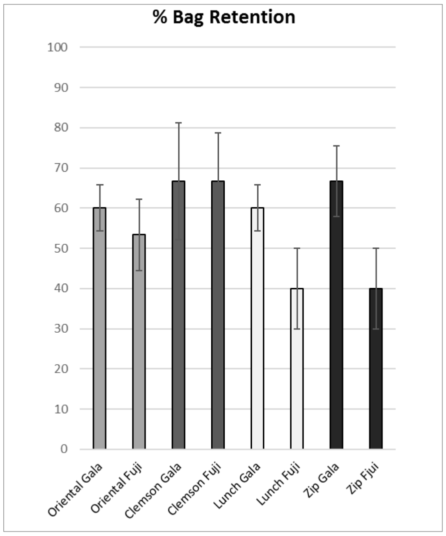

Figure 1. Percent bag retention for treatments (bags) and for host cultivars Gala and Fuji. Error bars indicate variation among replications.

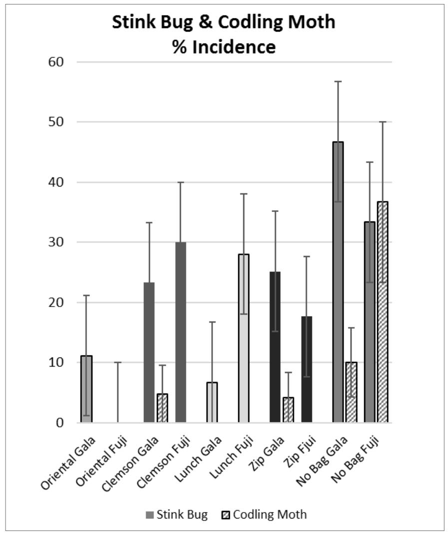

Figure 2. Stink bug and codling moth incidence (%) for treatments (bags) and host cultivars. Error bars indicate variation among replications.

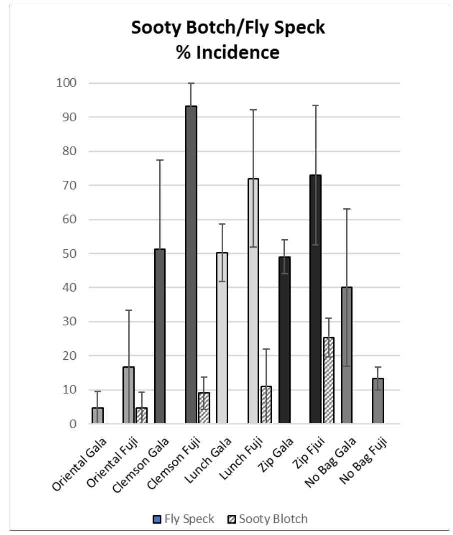

Figure 3. Sooty blotch and fly speck incidence (%) for treatments (bags) and for host cultivars. Error bars indicate variation among replications.

cantly fewer "other" rots in bagged treatments compared to the non-bagged treatments in the 'Fuji' (Oct) plots.

Summary and Discussion

Bag retention was equivalent for all bags in the earlier-harvested plots, but lunch bags were less resilient later in the season. During the course of the season, lunch bags degraded more quickly than the other bags made of paper. Stink bug damage was highly variable, so it was more difficult to separate treatment efficacy. Codling moth was controlled with all bag types in both early- and late-season plots. Sooty blotch and fly speck were more severe in Clemson, lunch, and plastic bags by the late-season harvest. Plastic bags held more condensation and may explain high incidence of sooty blotch/flyspeck in these treatments. Fruit rots were more severe in non-bagged fruit; all bag types were effective in managing fruit rot.

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Figure 4. Insect damage for treatments (bags) and for host cultivars. Means with asterisk* in the same column are statistically different from those without an asterick* (Fisher's LSD p≤0.05).

Treatment	Stink Bug Incidence %	Stink Bug Punctures per Fruit	Codling Moth Incidence %	Codling Moth Strikes per Fruit	Plum Curculio Incidence %	Plum Curculio Strikes per Fruit	San Jose Scale Incidence %
Gala Harvest 8-29-18							
Oriental	11.11	0.22	0.00	0.00	5.56	0.06	0.00
Clemson	23.28	0.27	4.76	0.05	0.00	0.00	0.00
Lunch	6.67	0.07	0.00	0.00	0.00	0.00	0.00
Zip	25.12	0.63	4.17	0.04	4.17	0.04	0.00
Control, non-bagged	46.67	1.97	10.00*	0.10	0.00	0.00	0.00
Fuji Harvest 10-10-18							
Oriental	0.00*	0.00	0.00	0.00	4.67	0.05	0.00
Clemson	30.00	1.90	0.00	0.00	3.67	0.07	0.00
Lunch	28.00	0.95	0.00	0.00	0.00	0.00	0.00
Zip	17.67	0.27	0.00	0.00	9.33	0.09	0.00
Control, non-bagged	33.33	1.07	36.67*	0.90*	10.00	0.10	0.00

Figure 5. Disease damage for treatments (bags) and for host cultivars. Means with asterisk* in the same column are statistically different from those without an asterick* (Fisher's LSD p≤0.05).

Treatment	Fly Speck Incidence %	Fly Speck Clusters per Fruit	Sooty Blotch Incidence %	Bitter Rot Incidence %	Bitter Rot Lesions per Fruit	Other Rot Incidence %
Gala Harvest 8-29-18						
Oriental	4.76*	0.05	0.00	0.00	0.00	0.00
Clemson	51.32	1.10	0.00	0.00	0.00	0.00
Lunch	50.16	0.68	0.00	0.00	0.00	0.00
Zip	49.05	1.06	0.00	0.00	0.00	0.00
Control, non-bagged	40.00	0.40	0.00	16.67*	0.23	0.00
Fuji Harvest 10-10-18						
Oriental	16.67*	0.25	4.67*	4.67	0.05	0.00
Clemson	93.33	4.95	9.00	3.67	0.04	0.00
Lunch	72.00	2.22	11.00	11.33	0.33	0.00
Zip	73.00	3.15	25.33	4.67	0.19	0.00
Control, non-bagged	13.33*	0.30	0.00*	20.00	0.67	16.67*

Rootstock Effects on Apple Tree Growth and Yield

Dwight Wolfe, Doug Archbold, Daniel Becker, June Johnston, and Ginny Travis, Horticulture

Introduction

Although apple and peach are the principal tree fruits grown in Kentucky, the hot and humid summers and heavy clay soils make their production more difficult here than in some neighboring tree fruit producing regions and can lead to high disease and insect pressure in Kentucky orchards. Despite these challenges, orchards can offer high per-acre income and are suitable for rolling hills and upland soils.

Identification of improved rootstocks and cultivars is fundamental for advancing the Kentucky tree fruit industry. For this reason, Kentucky cooperates with researchers from 29 other states in the United States, three Canadian provinces, Mexico, and Chile in the Cooperative Regional NC-140 Project entitled, "Improving Economic and Environmental Sustainability in Tree Fruit Production through Changes in Rootstock Use." The NC-140 trials are critical to Kentucky growers, allowing access to and testing of new rootstocks from around the world (Table 1). The detailed and objective evaluations allow growers to select the most appropriate rootstocks for Kentucky.

Materials and Methods

Grafts of known cultivars on the various rootstocks were produced by nurseries on the West Coast and distributed to cooperators. Cooperating sites participating in the 2010 apple rootstock trial that used Honeycrisp as the scion cultivar included BC, CHIH (Chihuahua, Mexico), CO, IL, IN, IA, MA, MN, MI, NJ, NY-Geneva, OH, UT, and WI. Sites that used 'Aztec Fuji' as the scion cultivar included CHIH, ID, KY-Princeton, NC, NY-Hudson Valley, PA, and UT.

For the Princeton, KY site, **t**hirty-one different rootstocks with 'Aztec Fuji' as the scion cultivar (Table 2) were compared in a randomized complete block experimental design with four blocks with from one to three trees per rootstock per block. The trees were planted in March 2010, on a 6- by 15-foot spacing, and trained to the tall spindle system. Trickle irrigation was installed a month after planting. Heavy spring rains resulted in many of the graft unions sinking below ground level. Many of the trees were dug up, reset, and allowed to resettle through the summer of 2010. The heights of the graft unions above the soil line average 5 inches with a range of 3 to 7 inches.

Orchard floor management for this trial consists of 6.5 feet of bare ground, herbicide-treated strips with mowed sod alleyways. Trees are fertilized and sprayed with pesticides according to local recommendations (Bordelon et al, 2018). For the 2018 growing season, mortality, yield (total weight of fruit harvested per tree), and trunk circumference measurements were recorded. Trunk cross-sectional area (TCSA) is calculated from the trunk circumference measurements taken 12 inches above the graft union. Cumulative yield efficiency was calculated by dividing the sum of each year's yield from 2012 thru 2018 by this year's trunk cross-sectional area. The cumulative yield efficiency is an indicator of the proportion of nutrient resources a tree is putting into fruit production relative to vegetative growth. Fruit size is calculated as the average weight (oz.) per fruit. Data on tree height and number of root suckers was reported in 2017 (Wolfe, et al, 2017), and will not be reported here. All data is statistically analyzed using SAS v.9.4 (SAS Institute Inc., Cary, NC, USA).

Table 1. Rootstocks in the 2010 apple rootstock trial with 'Aztec Fuji' as the scion cultivar.

Rootstock	Clone status	Breeding Program—Location
B.9	named	Budagovsky—Michurinsk State Agrarian University, Michurinsk, Tambov Region, Russia
B.10		
B.7-3-150	not released	
B.7-20-21		
B.64-194		
B.67-5-32		
B.70-6-8		
B.70-20-20		
B.71-7-22		
G.11	named	Cornell-Geneva—New York State Agricultural Experiment Station
G.41 N (stool bed produced)		
G.41 TC (tissue culture produced)		
G.202 N (stool bed produced)		
G.202 TC (tissue culture) produced)		
G.214 (formerly CG.4214)		
G.814 (formerly CG.4814)		
G.222 (formerly CG.5222)		
G.935 N (stool bed produced)		
G.935 TC (tissue culture produced)		
CG.2034	not released	
CG.3001		
CG.4003		
CG.4004		
CG.4013		
CG.5087		
Supp.3	named	Pillnitz—Institut fur Obstforschaung, Dresden-Pillnitz, Germany
PiAu.9-90	not released	
PiAu.51-11		
M.9 NAKBT337	named	NAKB clone of M.9— NAKB, Netherlands
M.9 Pajam2	named	CTIFL clone of M.9— CTIFL, France
M.26 EMLA	named	E. Malling clone of M.26— East Malling Res. Station, Kent, England

[1] For more information on Geneva rootstocks, see: http://www.ctl.cornell.edu/plants/GENEVA-Apple-Rootstocks-Comparison-Chart.pdf.

Table 2. 2018 results for the 2010 NC-140 apple rootstock trial, Princeton, KY.

Rootstock[1]	Initial Number of Trees	Tree Mortality (% lost)	Average Yearly Yields (2012-2018) (lbs./tree)	2018 Yield (lbs./tree)	Fruit Weight (oz./fruit)	TCSA (sq.in.)	Cum. Yield Efficiency (2012-2018) (lbs./sq. in TCSA)
PiAu 9-90	4	0	26.4	43.3	5.2	25.5	9.0
B.7-3-150	12	0	36.2	77.2	5.6	21.4	12.3
B.70-6-8	11	0	28.4	52.7	5.7	20.9	10.0
B.64-194	7	29	27.4	54.0	6.1	20.0	9.7
PiAu 51-11	11	9	29.9	50.9	5.9	19.5	11.6
B.67-5-32	12	8	32.0	73.8	5.3	17.6	13.2
M.26 EMLA	11	55	34.1	82.1	5.7	16.8	14.3
G.935 TC	4	25	29.7	52.4	5.8	16.4	12.8
G.202 N	8	0	36.6	82.3	5.8	14.1	20.2
G.222	8	0	39.3	95.3	5.9	13.3	21.2
CG.3001	3	0	26.2	61.3	6.1	12.7	14.3
CG.814	4	0	40.1	82.7	5.3	11.5	24.7
M.9 Pajam2	9	56	35.1	79.2	5.2	11.5	22.7
G.935 N	10	10	40.7	57.3	5.7	11.3	25.9
CG.4004	4	0	43.1	68.5	6.1	10.6	30.1
CG.5087	2	0	33.5	58.3	6.4	10.3	23.8
G.11	8	13	31.3	68.7	5.8	9.9	23.7
M.9 NAKBT337	12	67	31.4	60.3	5.3	9.9	24.9
G.214	4	0	32.5	79.1	5.4	9.8	23.5
G.202 TC	12	0	33.8	65.0	5.3	9.5	25.9
CG.4013	2	0	26.7	26.3	4.4	9.3	19.8
G.41 TC	1	0	27.3	32.6	6.0	9.2	20.8
Supp.3	5	60	23.1	12.2	4.4	8.5	19.0
B.10	12	8	29.1	44.9	5.4	8.4	24.5
G.41 N	3	0	33.0	62.9	5.5	7.2	32.5
CG.4003	7	0	26.6	60.3	3.9	5.8	33.6
CG.2034	2	50	21.0	55.4	6.6	5.2	28.7
B.9	12	17	13.2	19.4	3.9	2.9	32.8
B.7-20-21	12	0	5.5	7.5	3.1	2.8	14.1
B.71-7-22	10	30	9.4	21.8	5.4	2.2	31.7
Means	NA	15.8	29.0	56.6	5.3	12.2	20.4
LSD (5%)[2]	NA	40.4	13.9	61.4	1.3	5.8	11.4

1 Arranged in descending order of the fall trunk cross-sectional area (TCSA) for each rootstock.
2 Least significant difference (LSD) at the 5% probability level. Differences between two numbers within a column that are less than the LSD value are not significantly different.

Results and Discussion

In 2012, a tree with G.11 as the rootstock was lost due to deer damage, a tree on B.9 broke at the graft union, and two trees with M.9 NAKBT337 were lost, possibly from winter injury. Three trees (one M.9 Pajam2 and two B.71-7-22) succumbed to fire blight infections in 2013, and seventeen trees succumbed in 2014 to fire blight (including two B.64-194, five M.26 EMLA, two Supporter 3, one PiAu51-11, four M.9 NAKBT337, and three M.9 Pajam2). In 2015, a tree on G.935 N broke at the graft union, and three trees succumbed to winter injury (two B.70-20-20 and one M.9 Pajam2). In 2016, one tree on B.10, one on CG.2034, and one on M.26 EMLA, broke at their graft unions. One tree on B.71-7-22 was lost to fire blight. In 2017, five more trees were lost, one on G.935 TC (winter injury), two on M.9 NAKBT337 (fire blight), one on B.67-5-32 (broke at graft union), one on Supporter 3 (fire blight). In 2018, one tree on B.9 succumbed to winter injury. As reported previously (Wolfe, et al, 2017), NC-140 cooperators agreed to discontinue the evaluation of B.70-20-20 as it has proven to produce trees too large for high-density plantings. Consequently, this rootstock was removed from this trial in January 2016.

Mortality, average annual yield for the years 2012 through 2018, yield per tree for 2018, average weight per fruit, TCSA, and cumulative yield efficiency, varied significantly among the 30 rootstocks (Table 2). M.9 NAKBT337 had the highest tree mortality (67 percent), but this was not significantly different from Supp. 3, M.9 Pajam2, M.26 EMLA, CG.2034, B.71-7-22, or B.64-194. The three Malling rootstocks in this trial are typically considered to be industry standards throughout many apple-producing regions but have had survival rates of less than 50 percent due to their susceptibility to fire blight.

PiAu.9-90 rootstocks produced the largest trees in terms of TCSA, but they were not significantly larger than trees on B.7-3-150, B.70-6-8, or B.64-164. Similarly, B.71-7-22 produced the smallest trees, but they were not significantly smaller than trees on B.7-20-21, B.9, CG.2034, CG.4003, or G.41N. Yield in 2018 was greatest for G.222, which was not significantly more than that of G.41TC, and CG.4013. The average yield per year for the years 2012 thru 2018 was highest for trees on CG.4004, followed by G.935N, G.814, G.222, and G.202N. Fruit size (as measured by average fruit weight) ranged from 6.6 ounces for CG.2034 down to 3.1 ounces for B.7-20-21. CG.4003 had the highest cumulative yield efficiency, followed by B.9, G.41N, B.71-7-22, and CG.4004.

The tree size potential and performance of many of the rootstocks in this trial, particularly the Pillnitz and most of the Budagovsky rootstocks, were unknown prior to planting this trial, and have proved to be too vigorous for the tall spindle system in KY. When the vigor of these rootstocks is classified based on their relative size to M.9 NAKBT377 (Table 3), one can see the wide range of dwarfing among these stocks. Overly vigorous rootstocks compete for water, nutrients, and light with smaller rootstocks to the point of limiting the growth and yield potential of the smaller of stocks. Similarly, the performance of overly vigorous rootstocks is compromised by the six-foot-between-tree spacing.

Another problem with this trial is that trees of B.7-20-21 and B.70-6-8 performed so differently between the trials with Honeycrisp as the scion and those with Fuji as the scion that these two rootstocks are suspected of being misidentified in the nursery. Other problems related to handling by the nursery before plants were received include loss of trees that collapsed shortly after they leafed out, and inconsistencies with the tissue culture derived Geneva rootstocks (designated by "TC" after the rootstock name) compared to stool-bed produced trees (designated by "N"). These problems have been discussed recently in a Fruit Facts newsletter (Wolfe. D 2018). All of these problems complicate the statistical analysis, resulting in this trial being terminated a couple of years earlier than the ten years that rootstock trials normally run. Consequently, this is the final report on this trial.

The top performing rootstocks in this trial based on survival, yield, yield efficiency and fruit size were G.41N, CG.4004, CG-4003, and G.222.

Table 3. Relative vigor classification of apple rootstocks in the 2010 NC-140 apple rootstock trial at Princeton, KY.

Vigor Class[1]	Rootstock	TCSA	Cumulative Yield Efficiency (2012-2018) (lbs. /sq. in. of TCSA)	Percent Size Relative to Size of M.9 NAKBT337
Large Semi-dwarf (200% or more)	B.7-3-150	21.4	12.3	216.2
	B.70-6-8	20.9	10.0	211.1
	B.64-194	20.0	9.7	202.0
	PiAu 9-90	25.5	9.0	257.6
Moderate semi-dwarf (150-200%)	M.26 EMLA	16.8	14.3	169.7
	B.67-5-32	17.6	13.2	177.8
	G.935 TC[2]	16.4	12.8	165.7
	PiAu 51-11	19.5	11.6	197.0
Small semi-dwarf (130-150%)	G.222	13.3	21.2	134.3
	G.202 N[2]	14.1	20.2	142.4
Moderate dwarf (80-110%)	CG.4004	10.6	30.1	107.1
	G.202 TC	9.5	25.9	96.0
	M.9 NAKBT337	9.9	24.9	100.0
	B.10	8.4	24.5	84.8
	CG.5087	10.3	23.8	104.0
	G.11	9.9	23.7	100.0
	G.214	9.8	23.5	99.0
	G.41 TC	9.2	20.8	92.9
	CG.4013	9.3	19.8	93.9
	Supp.3	8.5	19.0	85.9
Small dwarf (40-80%)	CG.4003	5.8	33.6	58.6
	G.41 N	7.2	32.5	72.7
	CG.2034	5.2	28.7	52.5
Sub-dwarf (0-40%)	B.9	2.9	32.8	29.3
	B.71-7-22	2.8	31.7	22.2
	B.7-20-21	2.2	14.1	28.3
Least significant difference (0.05)		5.8	11.4	

1 Vigor class is based on relative size of trunk cross-sectional area to that of M.9 NAKBT337. For example, the trunk cross-sectional area of the large semi-dwarf class of rootstocks is over 200% of that of M.9 NAKBT337. Within a class, rootstocks are arranged in descending order of cumulative yield efficiency.

2 TC and N indicate tissue culture produced and bench propagated, respectively.

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Broccoli Cultivar Trial in Western Kentucky, Fall 2017

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Introduction

Broccoli has strong local demand, but commercial production is limited due to a deficiency of information on adapted cultivars and growing practices. In Kentucky, broccoli retails mainly as crown-cuts, or heads over 4 inches in diameter, that are sold as a single unit. Production occurs mainly in the fall. Growing quality heads is difficult in the spring due to weather variability and rapid warming. This trial evaluated fourteen cultivars for fall crown-cut production on a Crider Silt Loam soil field site at the UK Research and Education Center in Princeton, KY, located in the state's western region.

Materials and Methods

Broccoli were seeded on 18 July and grown for six weeks in fifty-cell plastic plug trays filled with BM2 Germinating Mix (Berger, Inc.). Starting 14-days after emergence seedlings were fertilized at weekly intervals, twice with 0.8 oz. (4 tsp)/gallon of 12-48-8 Sol-U-Grow (Miller Chemical & Fertilizer Corp.) and then 20-20-20 at the same rate. The incidence of leaf feeding caterpillars was low, requiring only one 0.33 fl. oz. (2 tsp.)/gallon spray of Sevin XLR Plus (Bayer CropScience LP) during this period.

Small plant size and wet field conditions delayed transplanting until 31 August, two weeks after the ID-36 (Saha et al, 2016), 15 August latest recommended date. Each plot consisted of ten plants spaced 12-inches apart on 5-foot center-to-center black-plastic beds (8,712/A population) that were replicated three times in a randomized complete block design. Fertigation procedures followed ID-36 recommendations for cole crops. Scouting revealed low and scattered incidence of leaf feeding caterpillars in the plots; only two sprays of Danitol (1 pt./A) and Mustang Max (4 oz./A) were required for control.

Crown-cut heads were harvested when larger than four-inches in diameter and included a six-inch attached stem. Harvest began on 20 October and continued weekly through 7 December. Heads were weighed, measured for size using a ruler, and rated for quality characteristics. SAS software (SAS Institute, Cary, NC) was used to analyze data, subjecting it to analysis of variance (ANOVA) and separating means using Duncan's Multiple Range Test LSD. Results were considered significantly different if $P \leq 0.05$.

Results and Discussion

Near normal temperatures occurred during the Fall 2017 growing season at the trial site. Rainfall was 2 and 5 inches above average for the months of August and September (Kentucky Climate Center, 2017; Kentucky Mesonet, 2017). In August, the excess precipitation was more evenly dispersed than in September when 5.45 inches fell in a single event on the first of the month. Roughly, normal amounts of rain fell during the remainder of the year.

Delayed field establishment affected maturation and marketability as it extended vegetative growth later into the season when cooler than optimum growing conditions prevailed. Compared to a similar trial the previous year (Becker et al,

Table 1. Maturity, marketability, and culls of broccoli cultivars, Fall 2017.

	Marketable[1]								Cull		
Cultivar	Seed Source[2]	Days to Maturity[3]	Yield (lb./A)[4,5]		Heads (No/A)[6]		Mean wt. (oz.)		(%)[7]		Reasons for Culling
Emerald Crown	SK	56-78	8,591	a	8,389	a	16.4	a	4.7	d	Small size
CLX3518	HM	62-82	8,345	ab	8,389	a	15.9	ab	9.3	cd	Small size, 7% had hollow stem
2709	S	56-78	8,147	ab	8,389	a	15.5	abc	0.0	d	No heads culled for deficiencies
SGD65282	SY	56-78	8,004	ab	8,067	ab	15.9	ab	4.1	d	Poor compactness
Eastern Crown	SK	62-82	7,837	ab	8,067	ab	15.5	abc	11.0	cd	Small size
Asteroid	HM	67-90	7,232	bc	8,067	ab	14.3	cd	2.8	d	Small size
Millennium	SK	70-90	6,866	bc	7,099	abc	15.4	bcd	7.7	cd	Small size
Eastern Magic	SK	74-98	6,541	bc	7,421	abc	14.1	de	8.0	cd	Small size
Emerald Star	SK	74-98	5,690	cd	6,131	cd	14.9	bcd	17.7	bc	Small size
Avenger	SW	82-98	4,864	de	5,485	def	14.2	cde	24.8	ab	Small size, 22% had hollow stem
HYB3869	HM	95-98	4,433	def	5,485	def	12.9	ef	24.7	ab	Small size
Monflor8	SY	50-67	4,009	def	7,099	abc	9.0	g	17.0	bc	Leaf penetration
3560 xbc	SK	95-98	3,352	ef	4,195	de	11.9	f	32.4	a	Small size, poor compactness
BR120908	SY	95-98	2,876	f	3,872	e	11.9	f	22.6	ab	Small size, 19% had hollow stem
Significance[9]			***	***	***				**		

1 Marketability calculated using: $\sum i \rightarrow j$ (head weight * 8,712 per acre plant population, assuming 100% survival) / 10 plants per plot.
2 See Appendix A for seed companies and addresses.
3 Number of days recorded from transplant to first and last harvest.
4 Consists of well-shaped, compact heads, larger than four inches in diameter with characteristic color and without damage or defects such as leaf penetration or hollow stem.
5 Means within columns separated using Duncan's Multiple Range Test LSD ($P \leq 0.05$). Two means having one or more of the same letters are NS.
6 Number of marketable heads per acre calculated using: # of marketable heads per plot * 871.2
7 Cull percent by weight calculated using: cull yield / (total yield of cull + yield of marketable heads).
8 Monflor is a bunching-type cultivar.
9 ** or *** Significant at $P \leq 0.01$ or 0.001, respectively, based upon general linear model analysis of variance test.

2017), maturation of Eastern Crown, Asteroid, Millennium, and Emerald Star was approximately 10 days slower (55-85 in 2016 vs. 62-98 in 2017) than expected. Cultivars harvesting 82 days from transplant and later were most affected as plant growth slowed dramatically with shortening day length and following a 22.3°F freeze on 20 November. Head damage was not observed until 8 December when a 19.7°F freeze cut short the harvest of Avenger, HYB3869, 3560 xbc and BR12-0908, negatively affecting yield, head size and quality characteristics (tables 1 and 2). Unmarketable culling was mostly due to small size, but Avenger and BR12-0908 also had a high rate of hollow stem. Overly rapid growth during heading will cause hollow stem in sensitive cultivars. Narrower spacing and lower nitrogen fertility rates can lower the incidence of hollow stem for crown cut broccoli.

Table 2. Diameter and quality characteristics of broccoli cultivars, Fall 2017.

	Diameter (in)		Head Quality Characteristics (1-5)				
Cultivar	**Head**	**Stem**	**Color[1]**	**Shape[2]**	**Compactness[3]**	**Leaf Penetration[4]**	**Bead Size[5]**
Emerald Crown	6.5	1.4	4.3	4.8	4.7	4.7	4.3
CLX3518	6.5	1.5	4.4	4.6	4.4	4.9	4.3
2709	6.3	1.5	4.4	4.3	4.6	4.9	4.2
SGD65282	6.3	1.4	4.5	4.4	4.5	4.8	3.8
Eastern Crown	6.3	1.4	4.6	4.6	4.7	4.8	4.4
Asteroid	6.1	1.4	4.7	4.2	4.5	4.8	4.0
Millennium	5.5	1.4	4.3	4.7	4.8	4.9	4.6
Eastern Magic	5.6	1.5	4.4	4.5	4.5	4.8	4.6
Emerald Star	4.7	1.4	4.3	4.5	4.6	4.7	4.4
Avenger	4.4	1.4	4.4	4.4	4.5	4.6	4.7
HYB3869	5.0	1.5	4.6	4.3	4.3	4.7	3.8
Monflor[8]	5.7	1.4	4.4	2.8	3.4	4.5	4.2
3560 xbc	4.5	1.4	4.7	3.5	3.8	4.7	4.6
BR120908	4.5	1.5	4.4	4.3	4.6	4.8	4.1
Significance[7]	***	NS	NS	***	***	NS	***

[1] Color rating scale: 1 = off-colored, 2 = yellow, 3 = light green, 4 = green, 5 = dark green or blue/purple-green.
[2] Shape rating scale: 1 = sunken, 2 = flat, 3 = low dome, 4 = moderate dome, 5 = high dome.
[3] Compactness rating scale: 1 = very loose, 2 = loose, 3 = moderate, 4 = compact, 5 = very compact.
[4] Leaf penetration rating scale: 1 = very heavy, 2 = heavy, 3 = moderate, 4 = light, 5 = none.
[5] Bead size rating scale: 1 = very large or coarse, 2 = large, 3 = moderate, 4 = small, 5 = very small or fine.
[6] Monflor is a bunching-type cultivar.
[7] NS or *** Not significant or significant at P ≤ 0.001, respectively, based upon general linear model analysis of variance test.

The best performing cultivars matured and were harvested within 56-82 days from transplant. Emerald Crown, Eastern Crown, and the numbered selections CLX3518, 2709, and SGD65282 had the greatest total yields along with corresponding head numbers and mean weights. All had superior quality and cull rates were low compared to later maturing cultivars. Hollow core was recorded in 7 percent of all CLX3518 stems, but the cull rate was not significantly higher than any of the other top cultivars. Emerald Crown especially was noted for consistently producing large, green heads that were compact and had a high dome shape. Domed heads are important for shedding moisture and reducing the incidence of soft rot.

This trial shows the high-risk nature of delaying broccoli transplant past the latest safe planting dates recommended in Table 1 on Page 135 of ID-36 for Western Kentucky and other growing regions. However, it also provides valuable information in situations where delayed planting is expected for whatever reason. Those cultivars which performed well in this trial should also perform well under similar situations.

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High Tunnel Summer Squash and Zucchini Cultivar Trial

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Introduction

Squash and zucchini (*Cucurbita pepo*) are popular summer vegetable crops that are generally considered simple to produce. However, they often succumb to various disease and insect pressures. Part of this disease pressure is from powdery mildew which can be influenced by rain that leaves moisture on leaf tissue. Although high tunnels are known for their usefulness during spring and fall for the shift in temperatures, they can also be used to control moisture on plants which can increase disease pressure. Using a high tunnel to produce squash in the summer may help reduce management costs and labor due to lower disease pressure. However, not all cultivars are suited for the high temperatures experienced in high tunnels compared to open field production. Additionally, certain cultivars may be appropriate for smaller, direct-to-consumer markets, but may not produce fruit uniform enough for larger markets, such as wholesale. The objectives of this trial were to evaluate cultivars not previously evaluated in Kentucky and assess appropriate cultivars for high tunnel production.

Materials and Methods

Four cultivars of yellow summer squash and three cultivars of zucchini squash were transplanted in a high tunnel (30 x 96 ft) on 8 June 2018 at the University of Kentucky Horticultural Research Farm in Lexington. The summer squash included the cultivars 'Gold Star,' 'Slick Pik,' 'Tempest,' and 'Zephyr.' The three zucchini cultivars were 'Costata Romanesco,' 'Dunja,' and 'Spineless Perfection' (Table 1). The trial was arranged as a randomized complete block design with five replications of the seven cultivars. The crop was transplanted on raised beds of Maury silt loam covered with black woven weed barrier mat on 5 ft centers. There was 18-inch spacing between each plant and seven plants in each treatment plot. The buffer space between each treatment plot within the same row was 2.5 ft.

Table 1. Cultivar characteristics.

Cultivar[1]	Squash type	Days to maturity[2]	Description
Gold Star F1	Yellow crookneck	50	Uniform fruit, nice shape; not many culled fruit
Slick Pik YS 26 F1	Yellow straight neck	48	Spineless; early producing, high yielding
Tempest F1 OG	Yellow crookneck	54	Nice color with subtle ribbing and striping; good yield
Zephyr F1	Yellow straight neck	54	Slender yellow fruit with green blossom end; virus appearance later in season; high number of culls
Costata Romanesco	Heirloom zucchini	52	Medium green with flecks and stripes; large blossom scar; lower yield due to high number of culls
Dunja F1 OG	Dark green zucchini	47	Large disease resistance package; uniform, straight fruit; high yielding
Spineless Perfection F1	Medium-green zucchini	45	Straight fruit, spineless plants; large disease resistance package

1 All seeds were purchased from Johnny's Selected Seeds.
2 Refers to average number of days from seeding to harvest.

Fertilizer was incorporated prior to shaping the beds at 50 lb. of N per acre (33.06 lb. of Nature Safe® 10N-0P-8K). Drip irrigation tape was installed at the same time the raised beds were formed and the weed mat was laid. Plant irrigation was maintained as needed based on soil moisture. Plants were maintained conventionally, including an application of imidacloprid insecticide (Admire® Pro; Bayer CropScience) through the drip irrigation line five days after transplanting to manage cucumber beetle pressure. Periodic aboveground fungicide applications were also used to control for powdery mildew. Applications included copper fungicide (Nordox 75 WG; Nordox) on 11 July and penthiopyrad fungicide (Fontelis®; DuPont™). We applied calcium nitrate weekly through the drip irrigation tape at a 7 lb/acre rate.

Fruit was harvested three times per week for four weeks beginning 27 June and ending 23 July for a total of 12 harvests. We determined fruit to be mature enough for harvest if it was at least 6 inches long. Marketable and unmarketable fruit were sorted based on USDA grading recommendations. Both marketable and unmarketable fruit were counted and weighed immediately after harvest. Data were subjected to an analysis of variance (ANOVA) test using Statistical Analysis System (SAS) statistical software (Version 9.4). Tukey was used to separate means when ANOVA tests were significant. Alpha was set at 0.05 for all data.

Results and Discussion

The 2018 summer growing season experienced more precipitation than normal. From the planting date to the last harvest, it rained 8.7 inches. This was 20 percent more precipitation than in the same time period in 2017 and 50 percent more than in 2016. Because it was being grown under the high tunnel, the precipitation during this time appeared to have a minimal effect on the squash/zucchini crop. However, Choanephora fruit rot was still one of the more common diseases on unmarketable fruit. Leaf wetness is considered a contributing factor to Choanephora fruit rot.

'Slick Pik' summer squash and 'Dunja' zucchini produced the highest marketable total yields for the entire season (Table 2). 'Slick Pik' and 'Dunja' also had the highest mean yields per plot, but were only significantly more than 'Gold Star.' 'Gold Star' produced the smallest fruit by weight, but was not significantly smaller than any of the yellow squash cultivars, only the three zucchini cultivars (Table 2). 'Costata Romanesco' had the heaviest fruit, but the lowest total yield. This cultivar produced large, dense fruit, but not a large quantity. It had low total yield, second only to 'Gold Star.' 'Tempest' had the third highest total marketable yield, but also had a high number of culled fruit (Table 2). Choanephora fruit rot was observed on

'Tempest' fruit and those fruit were culled. Viral symptoms were also observed on 'Tempest' fruit. 'Zephyr' was similar to 'Tempest' with a high culled fruit weight and number; marketable yield was also similar.

'Slick Pik' is advertised as an early producing cultivar. The first week of harvesting, it did have the highest mean weight of marketable fruit, although not significantly different from the other cultivars (Table 3). It produced 23 percent more than the next highest producer, 'Zephyr'. 'Slick Pik' also had consistent production through the harvest window. The average marketable yield did not vary more than 23 percent from the lowest producing week (Week 2) to the highest producing week (Week 4; Table 3). The second week of harvest was the only time period in which the mean marketable weights were significantly different from one another. 'Dunja' and 'Spineless Perfection' produced significantly more marketable fruit than 'Gold Star' and Zephyr' (Table 3).

'Dunja' and 'Slick Pik' performed consistently well and would be appropriate for larger-scale commercial high tunnel production in Kentucky. These two cultivars also produced uniform fruit throughout the season, making them more appropriate for wholesale markets compared to the other cultivars in the trial. However, both cultivars produce fruit that is considered standard, which may not attract customers in direct-to-consumer markets. 'Tempest' and 'Zephyr' produced moderate marketable yield compared to the other cultivars and produced fruit that is unique in appearance and may attract more customers at farmers' markets. 'Tempest' and 'Zephyr' may not be suitable for wholesale markets as these two cultivars did not produce uniform fruit throughout the harvest season.

Table 2. Total yield and weights.

Cultivar	Total marketable yield (lb)[1]	Mean marketable yield/plot (lb)[2]		Mean marketable fruit wt (lb)[4]		Total culled fruit (lb)	Mean culled fruit wt./ plot (lb)	
Gold Star	112.33	1.87	b[3]	0.35	c	6.51	0.11	b
Slick Pik	183.96	3.07	a	0.42	bc	13.78	0.23	b
Tempest	167.60	2.79	ab	0.47	abc	38.81	0.68	a
Zephyr	154.48	2.58	ab	0.45	bc	42.67	0.71	a
Costata Romanesco	123.00	2.05	ab	0.69	a	4.31	0.07	b
Dunja	181.93	3.03	a	0.60	ab	3.05	0.05	b
Spineless Perfection	141.20	2.35	ab	0.59	ab	5.86	0.10	b

1 Total marketable yield represents the yield from all treatment plots across all harvest dates harvested from five 18 ft^2 plots.
2 All plots consisted of 7 plants at the beginning of the trial.
3 Values within the same column followed by the same letter(s) are not significantly different at $P \leq 0.05$.
4 Calculated by dividing the marketable fruit weight by the number of marketable fruit.

Table 3. Mean marketable yield by week, beginning 27 June and ending 23 July.

Cultivar	Week 1[1] mean harvest (lb)	Week 2 mean harvest (lb)		Week 3 mean harvest (lb)	Week 4 mean harvest (lb)
Gold Star	5.08	5.23	bc2	5.68	6.48
Slick Pik	8.67	8.38	abc	8.81	10.93
Tempest	5.37	9.70	ab	9.23	9.22
Zephyr	6.70	9.10	abc	9.52	5.57
Costata Romanesco	3.95	4.73	c	8.25	7.67
Dunja	5.82	12.24	a	10.41	7.91
Spineless Perfection	4.31	10.12	a	7.36	6.45

1 Each week represents three harvests that occurred over the course of one week (7 days).
2 Values within the same column followed by the same letter(s) are not significantly different at $P \leq 0.05$.

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High Tunnel Carrot Planting Date and Cultivar Evaluation

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Tomatoes continue to be the most profitable crop for high tunnel production in Kentucky. As a result, tomatoes are repeatedly planted in high tunnels and crop rotation is often not practiced. This has led to high soil salt and fertilizer concentrations as well as soil borne disease problems that perplex growers and reduce marketable tomato yields. There is significant grower interest to determine other profitable high tunnel crops that may be rotated with tomatoes.

Nantes carrots are shorter, similar to Danvers carrots, but more cylindrical. They tend to be sweeter and work well in high tunnels because the season may be extended. Carrots require a loose, well-drained, friable soil to produce uniform roots without branching. Uniform, non-branching roots are essential to achieve U.S. No. 1 grading. Planting on heavy or rocky soils tends to result in stubby forked roots, which are generally not marketable.

This study was initiated to determine the best high tunnel winter/spring carrot (*Daucus carota* L.) planting date(s) and to evaluate four Nantes carrot cultivars for production and quality attributes in Kentucky.

Materials and Methods

Coated seed of four Nantes carrot cultivars (early crop 'Mokum', 'Yaya' and 'Napoli'; late crop 'Romance' all from Johnny's Selected Seeds) were planted by hand on 1 and 15 February, 1 and 15 March, and 2 April, spaced one inch apart at a depth of ¼-½ inch. Plots were replicated three times in a randomized block split plot design with planting dates as the main plots and carrot cultivars as sub plots. Nearly identical plantings were made in a gothic style high tunnel at the University of Kentucky Horticulture Research Farm in Lexington, and in a quonset-style high tunnel at the Robinson Center for Appalachian Resource Sustainability in Jackson, Kentucky. In Lexington, each plot row was three feet long with a 12-inch spacing between rows. In Jackson, the plot rows were two feet long in rows also 12 inches apart. The Lexington plots were grown on level ground (Maury silt loam soil); the Jackson plots were grown on raised beds of Nolin-Grigsby complex soil. Soil at both sites was amended with Nature Safe 8-5-5 organic, balanced fertilizer (Darling Ingredients, Irving, TX) for a pre-plant level of 50 lb nitrogen/acre. Soil and air temperatures were recorded at a three-inch depth and at a height of one foot, respectively, every 30 minutes with a Watchdog data logger (Spectrum Technologies, Aurora, IL) in the Lexington high tunnel. Both tunnels were drip irrigated as needed.

The first seedling emergence dates, and dates of 50% emergence were recorded. Data were collected on uniformity of stand, carrot root and top appearance, carrot yield, and cull number for each harvest date. For each planting date, all carrots of all cultivars were harvested on one day. Roots were rated for color, size, taste, bitterness, and sweetness.

Dr. George Antonious cooperated with us on this study and analyzed carrot sugar and phenolic contents. Sugar level is important in carrot taste and phenolic level provides a measure of antioxidant content. Reducing sugar and phenolic contents of carrots grown in Lexington were determined by chemical analyses. Replicate samples (n = 5) of carrot roots were collected at random from each cultivar at each harvest. The entire roots were cut into small pieces (1 cm^2 cubes) and representative subsamples (50 g) were blended with 150 mL of 80% ethanol. These samples were filtered through Whatman No. 1 filter paper (Fisher Scientific, Pittsburgh, PA) under a vacuum and 1 mL aliquots of filtrate were used for determination of total phenolics (McGrath et al., 1982) using a standard calibration curve (1 to16 µg mL–1) of chlorogenic acid. Soluble reduc-

Table 1. High tunnel soil and air temperatures, Lexington, KY.

Week Starting	Weekly Soil Temperatures[1] Mean (˚F)	Maximum (˚F)	Minimum (˚F)	Hours < 40 (˚F)	Weekly Air Temperatures[1] Mean (˚F)	Maximum (˚F)	Minimum (˚F)	Hours > 90 (˚F)
2/4/2018	44.4	52.4	38.2	16	39.1	64.2	22	0
2/11/2018	50.7	60.4	42.4	0	48.4	74.2	27.8	0
2/18/2018	55.8	63.9	44	0	57.6	80.6	28.9	0
2/25/2018	55.3	63.2	47	0	49.8	74.2	27.4	0
3/4/2018	51.6	61.7	42.7	0	43.9	77.5	22.2	0
3/11/2018	52.2	60.8	44.7	0	45.7	82.8	23.1	0
3/18/2018	52.3	64.8	42.4	0	45.7	88.9	24.6	0
3/25/2018	56.3	64.9	44.8	0	56.0	87.3	31.4	0
4/1/2018	57.8	70.4	49	0	52.9	102.8	25.3	3
4/8/2018	58.5	71	47.6	0	58.1	90.8	25.3	0.5
4/15/2018	59.8	72.1	49	0	54.4	97.4	31.1	4.5
4/22/2018	60.8	68.1	53.7	0	59.3	83.5	42.6	0
4/29/2018	65.6	75.2	52.4	0	65.7	92.8	32.2	2
5/6/2018	71.0	81.8	62.5	0	71.8	93.1	53.7	4.5
5/13/2018	75.5	84.3	70.5	0	75.7	98	64.4	17
5/20/2018	78.1	86.6	70.7	0	78.6	100.8	60.6	36.5
5/27/2018	77.2	83.6	71.8	0	76.9	100.2	65.2	19.5
6/3/2018	76.0	83.3	69.2	0	75.7	100.9	55.3	22.5
6/10/2018	77.5	84.7	73.3	0	77.4	102.3	62.6	25.5
6/17/2018	79.5	86.2	73.3	0	79.2	102.8	66.2	27.5

[1] Soil temperatures were recorded at a depth of 3 inches and air temperatures at a height of 1 foot at 30 minute intervals.

ing sugars, extracted with 80% ethanol, were quantified using the method described by Antonious et al., 1996. A calibration curve (10-50 µg mL–1) of pure glucose standard was applied.

Results and Discussion

Seed Germination

The minimum soil temperature for carrot germination is 40°F and the most desirable range for carrot soil germination is between 45°F and 85°F, with 80°F the optimum. The average Lexington high tunnel soil temperature for the week of 4 February was 44.4°F with a maximum of 52.4°F and a minimum of 38.2°F, with 16 hours below 40°F for this week (Table 1). These temperatures appear to be sufficient for carrot germination, although germination would be expected to be slow. It took an average of 25 days for the four carrot cultivars to emerge for the 1 February planting date, but only 11 days for emergence for the 2 April planting date (Table 6). Slow germination provides an extended period for soil microbes to attack young seedlings. As would be expected, soil and air temperatures gradually increased throughout the duration of this study (Table 1). A warming trend occurred during the last three weeks of February where soil and mean weekly air temperatures increased after which temperatures dropped and then began rising again. This warming trend led to problems with determining the earliest safe carrot planting date.

The highest weekly average soil temperature of 78.1°F was recorded for the week of 20 May with a maximum soil temperature of 86.6°F. Thus, soil temperatures were not high enough to inhibit germination. However, roots develop their best color when air temperatures are 60-70°F.

Air temperature maximums above 86°F were recorded beginning the week of 18 March and maximums above 100°F persisted from the week of 20 May to the conclusion of the study. Air temperatures above 86°F reduce foliage growth and roots develop strong flavors. High tunnels can heat up rapidly on cold sunny days and this is not conducive for quality carrot production, thus it is important for carrot growers to monitor air temperatures closely and roll the side curtains up on high tunnels in a timely manner.

Germination percentages in the Jackson tunnel ranged from 64 to 73 percent among cultivars and for the different planting dates, but showed no particular trend (tables 5 and 6). Seedling initial emergence as days after planting showed an expected declining number of days needed for germination for later planting dates as the soil and air temperature warmed (Table 6). It appears that emergence was slightly more rapid at the Jackson location and that the date of 50 percent emergence occurred fairly rapidly after first emergence. Stand uniformity by cultivar (Table 5) was not particularly good and shows the need for better germination percentages. This tended to decline at the Jackson high tunnel with later planting dates and showed no particular trend in the Lexington high tunnel. One confounding factor here is that it was noted part way through the Lexington study that the drip irrigation tubing was plugged and was not providing irrigation and as a result, 10 plots were dropped from the analysis.

Yields

Initial analysis showed that there was not a significant location effect, i.e., the yield results did not differ between the Lexington and Jackson locations. Consequently, data on yield and cull numbers from both locations were combined for analysis and yield data were adjusted to yields-per-10 feet of row to combine the data.

'Romance' produced the highest marketable yield and 'Yaya' the lowest, based on carrot number (Table 2). 'Romance' and 'Napoli' had the highest yields based on carrot weight and 'Mokum' and 'Yaya' the lowest. All cultivars had statistically similar, high numbers of cull carrots, at between 31 and 40 per 10 feet of row. There does not seem to be a trend in the number of marketable carrots based on planting date and there is no difference in marketable carrot weight among planting dates (Table 3). However, cull numbers are considerably higher for the last two planting dates, 15 March and 2 April, suggesting that later planting dates led to more culls. Root knot nematodes (*Meloidogyne sp.*) were found on carrots harvested at both locations and this also contributed to the higher number of cull carrots. Plant-parasitic nematodes had not been noted in either tunnel prior to this study, and carrots are particularly prone to root knot nematode infestation. There was no difference in the number or weight of marketable carrots harvested between the Jackson and Lexington locations (Table 4). However, higher numbers of cull carrots were harvested in Jackson. This may be a function of the heavier Jackson soil that

Table 2. Effect of cultivar on marketable and cull carrots, taste, bitterness, root appearance, length, and width.

	Marketable/10 ft Row[1,2]		Culls/10 ft Row	Taste[3]	Bitterness[4]	Sweetness[5]	Root Appear[6]	Root Length	Root Width	Sugars[7]	Phenols
Cultivar	(no)	(lb)	(no)	(1-5)	(1-5)	(1-5)	(1-5)	(in)	(in)	(ug/g Fresh wt.)	(ug/g fresh wt.)
Romance	34.3 a	4.0 a	40.8 a	3.0 b	4.5 a	1.1 c	4.3 a	6.9	1.1	5030 c	15.9 c
Napoli	29.3 ab	4.0 a	40.4 a	3.5 a	4.3 a	1.1 ab	3.9 ab	6.9	1.1	6042 b	17.8 c
Mokum	21.6 bc	2.3 b	31.9 a	3.7 a	4.6 a	1.0 a	3.8 b	6.3	1.0	5679 bc	20.9 b
Yaya	20.5 c	2.5 b	38.4 a	3.2 b	4.6 a	1.0 b	3.8 b	6.4	1.0	6826 a	26.8 a

[1] Marketable yield and cull numbers for both tunnel locations were analyzed together. Taste, bitterness, sweetness, root appearance (rated by two tasters), length, width, sugar and phenolic content are for the Lexington location.
[2] Means within the same column followed by the same letter are not significantly different (Duncan Multiple Range Test (LSD $P \leq 0.05$).
[3] Taste: 1 = poor; 3 = good; 5 = excellent.
[4] Bitterness: 1 = very bitter; 3 = slightly bitter; 5 = no bitterness.
[5] Sweetness: 1 = not sweet; 5 = very sweet.
[6] Root appearance: 1 = poor; 5 = excellent.
[7] Reducing sugars are about 10% of the total sugars.

would be expected to produce more forked carrot roots. Carrot root color was a uniform bright orange for all four cultivars and the tops were all disease free and an attractive dark green (data not shown).

Assuming 100 percent germination, a 10-foot section of row should have yielded 120 carrots. 'Romance' had an average yield of 34 marketable carrots and 40.8 culls (Table 2) which is not economically viable. A seed germination test of 50 seeds of each cultivar at the start of this study showed germination percentages ranging from 86 for 'Romance' and 'Yaya' to 94 percent for 'Napoli.' A high in-soil germination percentage, a heavier seeding rate with plant thinning, or additional or improved cultural techniques to increase germination are necessary to successfully grow carrots. Drip irrigation may not be the best irrigation technique to obtain high carrot germination percentages as a drip tube that is not located very close to the seed row may not sufficiently wet the soil for successful germination. The use of a plastic cover placed over the soil that would maintain moisture close to the soil surface is a cultural technique that would improve germination.

Table 3. Effect of planting date on marketable and cull carrots, root length, root width, sugar, and phenolic content in Lexington, KY.

	Marketable/10 ft Row[1,2]				Culls/10 ft Row		Root Length	Root Width	Sugars[3]		Phenols	
Planting	(no)		(lb)		(no)		(in)	(in)	(ug/g Fresh wt.)		(ug/g fresh wt.)	
Feb 1	28.8	ab	3.9	a	34.7	b	7.3	1.1	5827	a	14.6	c
Feb 15	20.9	b	2.7	a	31.9	b	7.2	1.1	6239	a	20.3	b
Mar. 1	33.2	a	3.1	a	33.0	b	5.9	1.0	6314	a	27.3	a
Mar 15	20.0	b	2.9	a	50.3	a	6.8	1.1	5361	a	19.9	b
Apr. 2	28.8	ab	3.4	a	40.3	ab	6.4	1.1	5136	a	18.4	b

1 Marketable yield and cull numbers for both tunnel locations were analyzed together. Root length, width, sugar, and phenolic content are for the Lexington location

2 Means within the same column followed by the same letter are not significantly different (Duncan Multiple Range Test (LSD P≤0.05).

3 Reducing sugars are about 10% of the total sugars.

Table 4. Effect of trial location on marketable and cull carrot counts.

	Marketable/10 ft Row				Culls/10 ft Row	
Location	(no)		(lb)		(no)	
Jackson	27.4	a	2.9	a	48.4	a
Lexington	25.2	a	3.6	a	25.3	b

Table 5. Effect of cultivar on germination percent, stand uniformity, and root size.

Location	Jackson	Jackson	Lexington	Jackson	Jackson
Cultivar	Germination (%)	Stand Uniformity[1] (1-5)	Stand Uniformity[1] (1-5)	Avg. Root Length (in)	Avg. Root Width (in)
Romance	67.5	2.9	3.3	3.8	0.6
Napoli	70.5	3.3	3.3	3.2	0.6
Mokum	63.6	2.7	2.8	2.9	0.4
Yaya	66.4	3.5	2.4	4.1	0.7

1 Stand uniformity: 1 = poor; 3 = good; 5= excellent.

Taste Evaluations

'Napoli' and 'Mokum' tasted better and tended to be slightly sweeter than 'Yaya' and 'Romance' at the Lexington Location (Table 2). 'Romance' was the least sweet of the four cultivars. No differences in cultivar taste nor sweetness were noted at the Jackson location (data not shown). There were no significant differences in cultivar bitterness noted by the two male taste evaluators in Lexington or the one male at Jackson. However, bitterness is perceived differently by 'supertasters.' Some taste studies have noted decreased taste sensitivity in older individuals and increased bitterness sensitivity by female tasters, while others have not. In light of this, one of the female authors tasted the later-planted Lexington carrots and noted bitterness where the male tasters did not. These data are not included because they were for only one planting date. 'Romance' produced the most attractive carrots closely followed by 'Napoli.'

There were no differences among planting dates for taste, bitterness, sweetness or root appearance (data not shown). There was a significant interaction between planting date and variety for bitterness, but not taste, sweetness, or root appearance. Bitterness did not vary among planting dates for 'Romance.' For the other varieties, low bitterness was associated with later planting dates. For 'Mokum' the least bitter carrots were those planted on 2 April, for 'Napoli,' the least bitter carrots were those planted on 1 March, and for 'Yaya,' the least bitter carrots were those planted on 15 March.

Reducing Sugar and Phenolic Contents

Reducing sugar and phenolic contents were measured in carrots from the Lexington tunnel. Reducing sugars differed among cultivars (Table 2), but not among planting dates (Table 3). Reducing sugar content of 'Yaya' was higher than the other three varieties and that for 'Romance' was the lowest. Its low reducing sugar content agrees well with its sweetness evaluation. There was no linear trend between planting date and sugar content because there were no differences in sugar content among planting dates (Table 3). In other words, earlier-planted carrots did not accumulate more sugar than later-planted ones. Phenolic content varied significantly among cultivars (Table 2) and planting dates (Table 3). 'Yaya' had the highest phenolic content and 'Romance' the lowest. The lowest concentration of phenolics was measured in carrots of the earliest planting date. The phenolic content of carrots planted on the latest date, 2 April were about 30 percent greater than for the first date, but lowest of the four remaining planting dates. Thus, there was no linear trend between planting date and phenolic content. Interestingly, replication was a very significant source of variation for both reducing sugar content and for phenolic content, suggesting that these characteristics are responsive to variation within the high tunnel environment.

Average root lengths and widths are shown in tables 2, 3, 5 and 6 for Lexington and Jackson, respectively. Carrot sizes were larger in Lexington than in Jackson even though the harvest dates were very similar for both locations.

Table 6. Effect of planting date on percent germination, seedling emergence, stand uniformity, days to harvest, and root size.

Location	Jackson	Jackson	Lexington	Jackson	Jackson	Lexington	Jackson	Lexington	Jackson	Jackson
Planting Date	Germination (%)	Initial Emergence (Days after planting)	Initial Emergence (Days after planting)	50% Emergence (Days after Planting)	Stand Uniformity[1] (1-5)	Stand Uniformity[1] (1-5)	Harvest (Days after Planting)	Harvest (Days after Planting)	Avg. Root Length (in)	Avg. Root Width (in)
Feb 1	72.9	17	25	18	4.0	2.5	119	119	4.0	0.7
Feb 15	64.9	10	22	12	3.3	2.2	106	105	4.0	0.7
Mar 1	64.2	13	16	17	3.1	3.8	93	95	4.0	0.7
Mar 15	66.7	12	17	16	2.8	3.7	97	95	2.7	0.4
Apr 2	66.3	10	11	19	2.3	2.4	83	81	2.3	0.4

[1] Stand uniformity: 1 = poor; 3 = good; 5= excellent.

This was our first attempt at growing carrots in a high tunnel. Had this been a commercial venture, it would not have been considered profitable. Yields were very low due to poor carrot stands and carrot quality. Carrots germinated very well beginning 1 February at the Jackson location and not as well in Lexington. It appears that a soil temperature of at least 40°F is critical for seed germination and this should be a primary criterion in determining when to plant. High tunnel air temperatures adversely affected carrot sweetness and taste resulting in carrots that would not encourage repeat sales. In previous years, carrots planted in the fall in high tunnels and harvested during the winter at the Horticulture Research Farm have resulted in very high quality, sweet carrots. However, most Kentucky direct markets are not operating in the winter. Close monitoring of irrigation and an enhanced effort to reduce tunnel high temperatures on sunny winter/spring days are critical for marketable and profitable carrot production in high tunnels.

Acknowledgments

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Bacterial Spot Resistant Bell Pepper Cultivar Evaluation, Central Kentucky

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Introduction

Bell peppers have been a profitable crop in Kentucky for many years. During this time bacterial spot has continued to reduce yields, because the species of bacteria causing this disease keeps evolving, allowing it to overcome bacterial spot resistance bred into the latest bell pepper cultivars. Consequently, bacterial spot resistance is a major selling point for new cultivars. Some of the newer ones have resistance to ten races (genetic variants) of *Xanthomonas campestris*, the species of bacteria responsible for most cases of pepper bacterial spot, while 'Aristotle' has resistance to three (Table 3). Resistance to a greater number of races reduce disease and can reduce the number of bactericide sprays, but the cultivars still have to yield well and have the quality that buyers require. Bell pepper breeders have developed cultivars producing a large number of U.S. Fancy grade peppers, however growers that sell to wholesalers who market fruit at a fixed price prefer cultivars that produce large percentages of U.S. No. 1 fruit. This replicated trial evaluated 15 bacterial spot-resistant bell pepper cultivars in comparison to the industry standard, 'Aristotle.'

Materials and Methods

Cultivars were seeded on 21 March into plastic plug trays (72 cells per tray) filled with Jiffy Seed Starting Mix 17 (Jiffy Products of America, Lorain, OH) at the University of Kentucky Horticultural Research Farm in Lexington. Greenhouse-grown transplants were set into black-plastic-covered, raised beds of Maury silt loam using a water wheel setter on 14 May. Plots were replicated four times in a randomized block design. Each plot was 10 ft. long and contained 20 plants set 12 in. apart in double rows spaced 15 inches apart on the bed. Beds were 5 ft. apart. Fifty pounds of nitrogen/acre as urea was applied prior to plastic laying. At planting each transplant was watered in with a pint of starter solution (6 lb. of 10-30-20 in 100 gallons of water). Calcium nitrate was applied via fertigation roughly weekly at a rate of 3.9 lbs. nitrogen/acre from 1 June through 9 September, for a total of 44 lbs. N/acre. No bactericide or fungicide sprays were applied, in order to better evaluate bacterial spot resistance. Danitol was sprayed for stink bug control on 9 and 15 August. Seven plants per plot were rated for disease severity using the Horsfall-Barratt scale, where each plant is given a numerical value depending on the total percent leaf area affected by bacterial spot.

The plot was harvested five times: 28 June, 16 July, 8 August, and 6 and 27 September. Fruit were weighed, counted and graded according to the grades U.S. Fancy (>3 in. diameter and height), U.S. No. 1 (>2.5 in. but <3 in. diameter), and U.S. No. 2 (<2.5 in. diameter plus misshapen but sound fruit sold as 'choppers' to food service buyers), and cull fruit.

Results

Average monthly temperatures during this trial began with May being 7°F above normal. June was 3°F above normal. July and August were near normal, and September was 5°F above normal. Precipitation was about normal in May and July, and 1.8, 1.3, and 4.7 inches above normal in June, August, and September, respectively. There were 24 days with precipitation from the planting date through 9 July (the last disease evaluation date) and this number of precipitation events is about average for that period. 'PS 8302' seeds germinated very slowly and the germination percentage was low. Consequently, there were only enough transplants to make three, instead of four trial replicates. A windy storm on 20 July broke many pepper-laden branches. This contributed to the high number of sun-scalded peppers. Foliage density appeared to vary among cultivars, and this likely contributed to the high scald incidence as well.

Most cultivars performed well with respect to yield (Table 1) and desirable fruit characteristics (Table 2). The best performing cultivars were selected by evaluating yield, slight differences in fruit characteristics, and for a few cultivars, past performance. Tables 4, 5, and 6 show results, by grade, of the

Table 1. Total yield and yield by USDA grades, 2018.

Cultivar	Total Marketable Yld (lb/A)[1,2]	U.S. Fancy (lb/A)[2,3]	U.S. No.1 (lb/A)[2,4]	U.S. No. 2 (lb/A)[2,5]	Cull (%)[6]	Fancy + No. 1 as % of Total Mkt Yield
La Belle	53,200 a	19100 a	14100 abc	20000 a	10	62
Aristotle	53,000 a	19500 a	13900 abc	19500 a	9	63
Playmaker	48,400 ab	16900 ab	14200 abc	17200 abcde	11	65
PS 0994-1819	46,900 abc	19100 a	10000 c	17800 abc	11	62
SV 9325	44,500 abc	15000 abc	10900 bc	18600 ab	13	58
Ninja S10	44,300 abc	15000 abc	11800 abc	17600 abcd	15	60
Samurai S10	43,900 abcd	14900 abc	16400 a	12600 cdef	10	71
Turnpike	43,700 abcd	16400 ab	13300 abc	14000 bcdef	16	68
Boca	43,600 abcd	14600 abc	15700 ab	13300 bcdef	10	69
Captiva	43,200 abcd	15600 abc	15500 ab	12000 ef	11	72
SDY 48	40,400 bcd	11700 bc	12600 abc	16000 a-f	14	60
Outsider	39,300 bcd	16600 ab	9700 c	13100 cdef	22	67
Standout	37,700 bcd	14200 abc	10700 bc	12900 cdef	16	67
Skyhawk	36,400 bcd	10500 bc	12400 abc	13600 bcdef	12	63
Hunter	35,000 cd	9000 c	13900 abc	12100 def	9	66
PS 8302	32,100 d	11400 bc	9100 c	11600 f	24	64

1 Includes yields of U.S. Fancy, No. 1, and No. 2 fruits.
2 Means in the same column followed by the same letters are not significantly different (Waller-Duncan test LSD P ≤.05).
3 U.S. Fancy = undamaged, unblemished, well-shaped fruit >3 in. dia. and height.
4 No. 1 = undamaged, unblemished, well-shaped fruit >2.5 but <3 in. dia.
5 No. 2 = undamaged, unblemished fruit <2.5 in. dia., plus larger, misshapen yet sound fruit which could be sold as 'choppers' to food service buyers.
6 Percent of all harvested fruit by weight having surface scarring, sunscald, insect and disease damage.

Table 2. Fruit characteristic ratings.

Cultivar	Silvering (%)[1]	Uniform Fruit Shape[2]	Fruit Appearance[2]	4-lobed Fruit (%)	Blockiness[3]	Green Color[4]	Sun-scalded Fruit (%)[5,6]
La Belle	11	4	4	60	4.2	4.2	5 a
Aristotle	5	4.1	4.2	33	4.4	4.1	4 a
Playmaker	3	4	3.9	60	4.3	3.6	6 abcd
PS 0994-1819	5	4	4.1	50	4.4	4.3	5 ab
SV 9325	1	3.9	4.1	45	4.2	4.4	9 bcde
Ninja S10	5	4	4	60	4.2	4.2	10 ef
Samurai S10	3	4.4	4.3	60	4.5	4.4	5 a
Turnpike	6	3.9	4.1	53	4.4	4.3	9 cde
Boca	5	4.2	4.3	50	4.2	4.4	4 a
Captiva	8	4.5	4.4	50	4.6	4.5	6 abc
SDY 48	8	4.1	4.1	58	4.4	4.4	9 bcde
Outsider	9	4.2	4.3	63	4.5	4.3	13 f
Standout	1	4.3	4.4	55	4.4	4.4	10 def
Skyhawk	5	4.1	4	43	3.9	4.1	5 a
Hunter	10	4.1	3.9	33	3.9	4.5	4 a
PS 8302	4	4.3	4.1	50	4.4	4.4	17 g

1 Percent of total marketable fruit count at 2nd harvest showing silvering (very fine, light-colored streaking).
2 1 = poor, 5 = excellent.
3 1 = long, slender fruit or very squat, flattened fruit, 5 = fruit with equal height and width.
4 1 = pale green, 5 = dark green.
5 Percent of all harvested fruit having sunscald.
6 Means in the same column followed by the same letters are not significantly different (Waller-Duncan test LSD P ≤.05).

early, middle, and latest harvests, respectively. This gives growers an idea of how the cultivars performed across the harvest period. (Most cultivars yielded little or nothing in the first harvest). The second and fifth harvests (Tables 4 and 6) yielded the most pounds of fruit across all cultivars, and were about equal. The third harvest (Table 5) produced about a quarter of the second harvest. This may have been due to very low bloom numbers observed in many cultivars in late June. Yields of the ten highest-yielding cultivars (total marketable yield) were not significantly different (Table 1). All ten also had the greatest yields of U.S. Fancy fruit, and these yields, too, were statistically similar. Eight of these also had the highest yields of U.S. No. 1 fruit. The best performing bell pepper cultivars in this trial were among this group:

- 'La Belle' had the highest total marketable yield for the entire trial and the second highest U.S. Fancy yield. It also had relatively low percentages of culled and sun-scalded fruit (Table 2), and one of the higher percentages of four-lobed fruit. Across all harvests, it had one of the lower average weights of individual fruit in the U.S. No. 1 grade, and maintained this trend throughout the trial (Table 8). Its 80 % pack out of Fancy + No.1 fruit in the second harvest (Table 7) makes it a good choice for the early market, however it tends to have a lighter fruit color and had the highest percentage of fruit with silvering (very fine, pale streaks on the skin).
- 'Aristotle' had the second highest total marketable yield, as it did in the 2017 pepper evaluation (Smigell et al, 2017). Essentially, 'La Belle' and 'Aristotle' had the same total marketable yields (26.5 tons/A). 'Aristotle' had a high average weight of individual fruit in the U.S. No. 1 grade across all harvests (Table 8). It had low scald, cull, and silvering percentages, however its percentages of four-lobed fruit have been among the lowest of all cultivars tested in this year's and last year's trials.
- 'Samurai S10' had the highest yield of No.1 fruit for the trial and the second highest percentage of total yield as Fancy + No. 1 fruit. It ranked very high in percentages of Fancy + No. 1 fruit in the second and third harvests (Table 7), making it a good cultivar for the early market. Its average weight of individual fruit in the U.S. No. 1 grade across all harvests was not significantly different from 'Aristotle' (Table 8). Cull, silvering, and scald percentages were among the lowest. It also had high rankings for all other fruit characteristics.
- 'Turnpike' ranked highest for percentage of Fancy + No. 1 fruit pack out in the last harvest, and so may be a good choice for the later market. Its overall percentage of total yield as Fancy + No. 1 fruit was higher than for 'La Belle' and 'Aristotle.' It had a low silvering percentage, good blockiness and color ratings, and was the highest yielder of marketable fruit in the 2017 trial. It maintained a high average fruit weight for No. 1 grade average across all harvests (Table 8).
- 'Boca' was among the highest yielders in 2017 and in this year's trial. It had the second highest overall yield of No. 1 fruit and a high percentage of Fancy + No. 1 fruit in the second harvest, consistent with its early harvest last year. Thus this is another good early market candidate. Its overall percentage of total yield as Fancy + No. 1 fruit was higher than

Table 3. Cultivar attributes.

Cultivar	Seed Source	Days to Harvest[1]	Ripe Fruit Color	Disease Resistances[2,3]	Fruit Comments
La Belle	SW	73	red	HR: BS 1-10	Many jumbo fruit; many distorted fruit; a few flattened fruit in last harvest
Aristotle	ST	70-75	red	IR: BS (1-3), PVY, TMV	Many distorted fruit; a few flat fruit, and lighter green color
Playmaker	SW	71	red	BLS 0-10 HR: TMV; IR: Phyt	Many lopsided/distorted fruit; attractive fruit in last harvest; a few flat fruit in last harvest
PS 09940-1819	SW	73	red	HR: BS 1-5; IR: Pc	Many jumbo fruit; 12 flattened fruit in last harvest
SV 9325	SW	-	red	HR: BS 1-10	Many flat fruit in last harvest; many tiny/lopsided ones at last harvest
Ninja S10	SW	72	red	IR: BS 1-10; HR: TMV	
Samurai S10	SW	72	red	IR: BS 1-10; HR: TMV	Few very large fruit in last harvest
Turnpike	SW	75	red	HR: BS (1-5, 7-9), TMV, Phyt	A lot of tall fruit, many pointy fruit; many jumbo sized & attractive fruit in last harvest 6 pointy; nice & tall
Boca	SW	73	red	HR: BS 1-10	Few very large fruit and a few flattened fruit in last harvest
Captiva	SW	-	red	HR: BS 1-10; IR: TSWV	Attractive fruit in last harvest; dark green fruit
SDY 48	SW	73	red	HR: BS 1-10	Many flat ones in last harvest
Outsider	SW	73	red	HR: BS 1-10	Many very large fruit in last harvest
Standout	SW	-	red	HR: BS 1-10	Many flattened fruit; and many tiny fruit in last harvest
Skyhawk	SW	72	red	HR: BS 1-10	Many distorted fruit; many flattened fruit in last harvest
Hunter	SW	71	red	HR: BS 1-5, 7-9, TEV, TMV	Not many very large fruit; blocky, dense
PS 8302	SW	-	red	HR: BS 1-5	Several very large fruit in last harvest

1 Days to harvest as listed by seed companies.
2 HR = highly disease resistant (restricted disease development & symptoms); IR = intermediate resistance (may show more disease symptoms than 'resistant' cultivars grown in same environment).
3 BS = bacterial spot (strains 1-10); Phyt = phytophthora root rot; TMV = tobacco mosaic virus; PVY = potato virus Y (strains 0, 1, and 1-2); TSWV = tomato spotted wilt virus: TEV = tobacco etch virus.

for 'La Belle' and 'Aristotle.' Silvering percentage was low, and cull and sunscald percentages were very low. It was rated very high for fruit appearance and its dark green color.

- 'Captiva' had the third highest yield of No. 1 fruit for the whole trial, and the highest percentage of total yield as Fancy + No. 1 fruit for the trial. It had the highest percentage (88%) of Fancy + No. 1 fruit in the second harvest, making it a good early market choice. Cull and scald percentages were low, and it had some of the highest marks for fruit shape, appearance, blockiness, and color.

Yields of U.S. Fancy and No. 1 peppers (as a percentage of total marketable yield) decreased for all cultivars from the second to the third harvest (Table 7), and for most cultivars the percentage decreased again in the last harvest, except for 'Playmaker,' 'Captiva,' 'Outsider,' and 'Turnpike.'

Maintaining individual pepper weight/size as the season progresses is desirable, but normally drops as the season progresses. Looking at all cultivars combined, just for the Fancy and No. 1 grades, average pepper weights were significantly lower for the later harvests compared to harvests in June or July (data not shown). Thus, on the whole, pepper size for these grades decreased as the season progressed. Comparing cultivars, all harvests combined, there were no significant differences in the average weight of a Fancy pepper (Table 8). Analysis of variance did indicate that the average weight of peppers in the No. 1 size grade differed among harvest dates for some cultivars (column 5, Table 8). 'Turnpike' was the only cultivar among the overall high-yielders that did not vary its average weight of No. 1 peppers through all five harvests.

In Figure 1 the vertical axis represents the average bacterial spot severity by cultivar after transforming the Horsfall-Barratt ratings to the midpoint of the rating range. Ratings were completed on 15 and 27 June, and 9 July. By the third evaluation, 'Hunter,' 'PS 8302,' 'Turnpike,' 'Captiva,' and 'Boca' showed trends of higher bacterial spot severity, and were statistically different from the grower standard Aristotle. Though 'Samurai S10' was numerically lowest in bacterial spot on all dates, this difference was not statistically different from most cultivars.

Table 4. Yields of second harvest, 16 July.

Cultivar	Total marketable yield (lbs)[1]	Percent of Total Mkt. Yield		
		Fancy (%)	No. 1 (%)	No.2 (%)
Aristotle	22125	57	17	26
La Belle	18667	60	21	20
Playmaker	16344	53	17	29
Standout	15210	67	23	11
SV 9325	14665	68	16	16
Skyhawk	14293	60	25	16
Samurai S10	13994	64	22	14
Ninja S10	13954	59	22	18
SDY 48	12841	62	16	22
Turnpike	12315	54	22	23
PS 0994-1819	12297	61	9	30
Outsider	12269	74	8	18
Boca	11963	62	19	20
Captiva	11915	68	20	12
Hunter	8349	61	26	14
PS 8302	7962	66	11	22

[1] Combined weights of Fancy, No. 1 and No. 2 fruit.

Table 5. Yields of third (middle) harvest, 8 August.

Cultivar	Total marketable yield (lbs)[1]	Percent of Total Mkt. Yield		
		Fancy (%)	No. 1 (%)	No.2 (%)
La Belle	7196	41	16	43
PS 0994-1819	6307	42	16	43
Standout	4447	45	22	34
SV 9325	4102	33	20	47
Aristotle	3975	40	11	49
Playmaker	3911	15	29	55
SDY 48	3539	27	28	45
Ninja S10	3267	24	25	52
Outsider	3122	44	4	52
Captiva	2949	16	47	37
Skyhawk	2868	29	23	48
Samurai S10	2605	38	29	33
Hunter	2251	45	27	28
Boca	2105	36	32	32
Turnpike	2006	28	30	42
PS 8302	1912	35	31	33

[1] Combined weights of Fancy, No. 1 and No. 2 fruit.

Table 6. Yields of fifth (last) harvest, 27 September.

Cultivar	Total marketable yield (lbs)[1]	Percent of Total Mkt. Yield		
		Fancy (%)	No. 1 (%)	No.2 (%)
Ninja S10	18695	20	29	52
La Belle	17950	14	32	53
Aristotle	16789	16	29	55
Boca	15663	14	44	42
Turnpike	15128	31	34	34
Playmaker	14720	25	29	45
Samurai S10	14620	16	35	49
PS 8302	14450	23	33	44
PS 0994-1819	14393	24	26	50
Captiva	14366	25	40	36
SV 9325	14320	8	26	67
Hunter	13821	9	44	47
Skyhawk	12787	8	37	55
Outsider	12142	23	38	40
SDY 48	11616	10	36	54
Standout	10373	8	33	59

[1] Combined weights of Fancy, No. 1 and No. 2 fruit.

Table 7. Combined percentages of U.S. Fancy and No.1 fruit at each harvest.

Cultivar[1]	% of U.S. Fancy + No. 1 Fruit[2]		
	Fancy (%)	No. 1 (%)	No.2 (%)
La Belle	80	57	47
Aristotle	74	51	45
Playmaker	71	45	55
PS 0994-1819	70	57	50
SV 9325	84	53	33
Ninja S10	82	48	48
Samurai S10	86	67	51
Turnpike	77	58	66
Boca	80	68	58
Captiva	88	63	64
SDY 48	78	55	46
Outsider	82	48	60
Standout	89	66	41
Skyhawk	84	52	45
Hunter	86	72	53
PS 8302	78	67	56

[1] Ranked by total-season yield.
[2] P of total marketable yields.

These levels of disease were still relatively low, as very few fruit were culled due to bacterial spot, and leaf spotting was not severe enough to become obvious in any cultivar.

Acknowledgments

The authors would like to thank the following for their hard work and assistance in the successful completion of this trial: Joseph "Jay" Tucker, Dave Lowry, Grant Clouser, Steve Diver, Mohammad Dawood, Ammar Al Bayati, Jackson "Cade" Laumas, Hnin Nu Hlaing and Nway Nway Aung. Funding for this project was provided by a grant from the Kentucky Horticultural Council through the Agricultural Development Fund.

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Table 8. Average pepper weights, all harvests combined[1].

Cultivar	All Marketable Peppers (lbs/pepper)[1]		Fancy (lbs/pepper)[1]		No. 1 (lbs/pepper)[1]		Did U.S. No. 1 avg. wt. vary among harvests?
Aristotle	0.4	abcd	0.48	a	0.35	abc	yes
Boca	0.38	abcd	0.48	a	0.33	abcd	yes
Captiva	0.4	abcd	0.48	a	0.35	ab	yes
Hunter	0.37	abcd	0.46	a	0.32	bcd	yes
La Belle	0.38	abcd	0.46	a	0.3	d	no
Ninja S10	0.38	abcd	0.54	a	0.3	d	no
Outsider	0.4	abcd	0.46	a	0.32	cd	no
Playmaker	0.41	ab	0.47	a	0.36	a	yes
PS 0994-1819	0.4	abc	0.48	a	0.32	bcd	yes
PS 8302	0.41	a	0.51	a	0.3	d	yes
Samurai S10	0.36	d	0.42	a	0.33	abcd	yes
SDY 48	0.36	cd	0.43	a	0.32	cd	no
Skyhawk	0.34	e	0.49	a	0.33	abcd	yes
Standout	0.37	abcd	0.45	a	0.33	abcd	yes
SV 9325	0.36	bcde	0.46	a	0.33	abcd	yes
Turnpike	0.39	abcde	0.49	a	0.34	abc	no

[1] Means within a column followed by the same letter are not significantly different as determined by Duncan's New Multiple Range Test ($P \leq 0.05$).

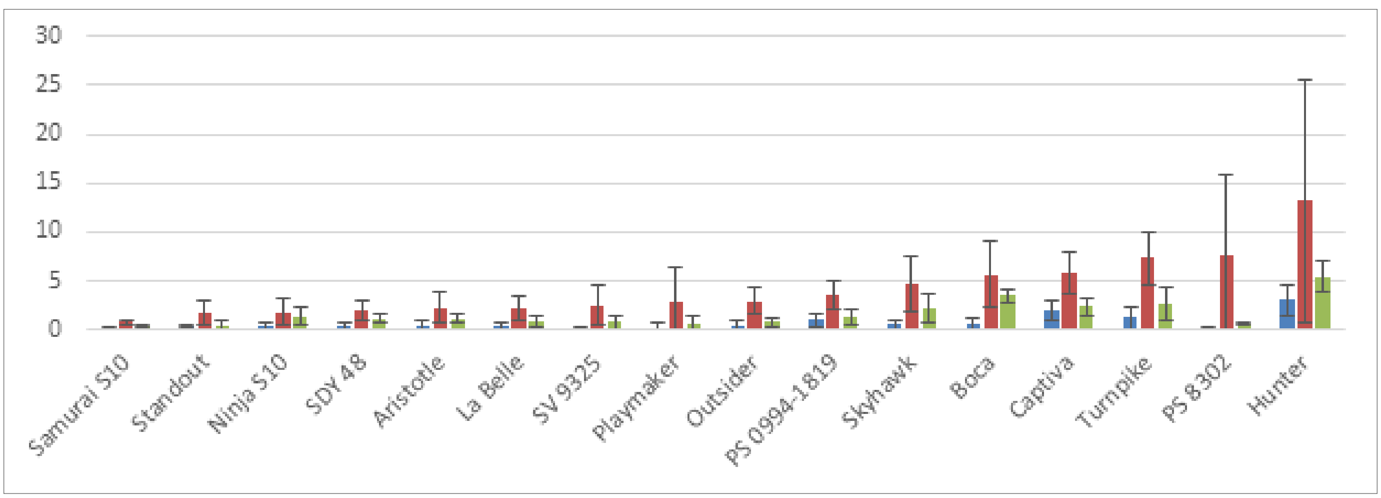

Figure 1. Seven plants per plot were rated for disease severity using the Horsfall-Barratt scale, where each plant is given a numerical value depending on the total percent leaf area affected. The vertical axis represents the avg. bacterial spot severity by cultivar after transforming the Horsfall-Barratt ratings to the midpoint of the rating range. Ratings were completed on 15 and 27 June, and 9 July (blue, orange, green bars, respectively).

Growing Eggplant in Biochar and Animal Manure Amended Soil

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Introduction

Eggplant, *Solanum melongena* L., is a Solanceaeus crop widely grown in the subtropics and tropics areas. It is a good source of soluble sugars, protein, anthocyanin, phenolic, and glycoalkaloid compounds. The phenolic antioxidants in eggplant has hepato-protective effect. Kentucky, having favorable weather for growing eggplant, has the potential to expand eggplant production and meet the growing market for fresh vegetables. Its characteristic feature is a root system of a medium range and its demand for water is greatest during the blooming and fruit-forming periods. Eggplant is sensitive to frost and the growth of young plants is constrained by temperatures below 16°C (61°F). The growth of eggplant may slow down when the temperature is too high (>30°C about 86°F), there is not enough water, or in the case of excessive humidity combined with a high temperature. High temperature and evenly distributed rainfall throughout the vegetation period are favorable conditions for eggplant yielding. The fruit shape range includes spherical, oblong, ovoid, oval, long and many intermediate shapes. The mean fruit weight is in the range of 200-300 g. Newer Asian types have weights of 20-40 g. Based on data from 2014, the global production of eggplant is around 50 million tons annually with a net value of more than $10 billion a year, which makes it the fifth most economically important Solanaceous crop after potato, tomato, pepper, and tobacco. The top five producing countries are China (28.4 million tons; 57 percent of world's total), India (13.4 million tons; 27 percent of world's total), Egypt (1.2 million tons), Turkey (0.82 million tons), and Iran (0.75 million tons). In Asia and the Mediterranean, eggplant ranks among the top five most important vegetable crops.

The use of soil amendments in agricultural production systems is an affordable way to improve crop yield and quality. Antonious et al. observed that sewage sludge mixed with yard waste compost provided the highest marketable yield and greatest number of eggplant fruits compared to no-mulch bare soil. Azarmi et al. reported that the addition of vermi-compost to agricultural soil increased tomato yield and elemental content of tomato as compared to no-mulch control treatments. Laczi et al. found that the best yield of the Chinese cabbage was obtained when horse manure was used as a soil amendment. In addition, recent studies indicated that biochar (a product of burning wood by a process known as pyrolysis) could increase plant nutrients, soil cation exchange capacity (CEC), soil organic matter, soil microbial activities, and nutrients availability.

Biochar is created by heating biomass at high temperature (300-1,000°C, which is equal to 572-1,832°F) under low oxygen conditions. Biochar application to agricultural soils has received increasing attention in recent years, due to the potential for climate change mitigation and improvement of soil properties linked with the increase of cation exchange capacity, nutrient and water retention, and positive influences on soil microbial communities, which influence crop yields. The objectives of this investigation were to: (i) assess the effect of seven soil treatments and biochar mixed with soil amendments on eggplant yield and number of fruits and (ii) investigate the effect of soil amendments on fruit quality characteristics as specified by the USDA eggplant standard guidelines.

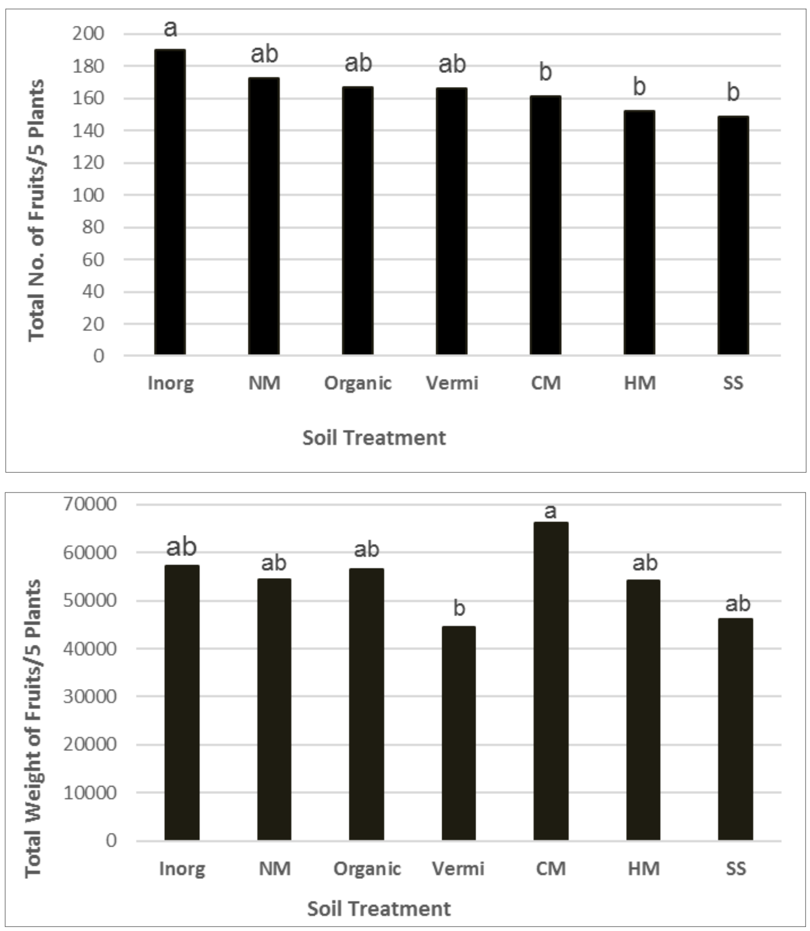

Figure 1. Number of eggplant fruits (upper graph) and weight of fruits (lower graph) of plants grown under seven soil management practices: inorganic fertilizer, no-mulch (NM), organic fertilizer, vermi-compost, chicken manure (CM), horse manure (HM), and sewage sludge (SS). Bars accompanied by different letter(s) in each graph indicate significant differences (P < 0.05) using Duncan's multiple range test.

Materials and Methods

A field experiment was conducted at the University of Kentucky Horticulture Research Farm in Lexington, KY. Forty-two field plots of 4 ft length and 10 ft width (4×10 ft2 each) were used in a randomized complete block design (RCBD). Treatments were: 1) control (no-mulch untreated soil); 2) sewage sludge (SS); 3) horse manure (HM); 4) chicken manure (CM); 5) vermi compost (worm casting); 6) organic fertilizer (Nature Safe 20:2:8); and 7) inorganic fertilizer (Southern States 19:19:19). Each of the seven treatments was also mixed with 10% (w/w) biochar obtained from Wakefield Agricultural Carbon (Columbia, MO) to make a total of 14 treatments. Sixty day old seedlings of eggplant, *Solanum melongena* var. 'Epic' were planted in a freshly tilled soil at 18-inch in-row spacing on May 17, 2017 and drip irrigated as needed. Weeding and other cultural operations were done regularly. Esfenvalerate (Asana XL) was applied three times at seven-day intervals at a rate of 5.5 fluid oz/acre to control Japanese and Colorado potato beetles. The eggplant fruits were harvested during the growing season and graded according to the USDA guidelines into: Fancy, U.S. No. 1, U.S. No. 2, and Culls (U.S. EPA 2013). U.S. Fancy fruits are well-colored, firm, well-shaped, and free from decay, disease or worm holes. U.S. No. 1 fruits are fairly well-colored, fairly well-shaped, and free of decay, disease or worm holes. U.S. No. 2 fruits are free from cuts, decay or serious damage caused by discoloration, or mechanical or other means. Culls are fruits that are not marketable due to presence of holes caused by disease and/or damage. At harvest eggplant yield, number of fruits, and fruit grading characteristics (Fancy, U.S. No. 1, U.S. No.2, and culls) were recorded and statistically analyzed using analysis of variance (ANOVA, SAS Institute Inc.).

Results and Discussion

Results revealed no significant differences ($P > 0.05$) among biochar and no-biochar treatments in crop yield, number of fruits, or fruit quality characteristics, indicating no impact of biochar on all the parameters tested in this study. The number of total fruit obtained from inorganic treatments were significantly greater compared to CM, HM, and SS treatments. Whereas, weight of fruit obtained from CM- treated soil was significantly ($P < 0.05$) greater compared to vermi-compost soil treatment (Fig. 1). This response may be due to increase nutrient availability, soil porosity, and water holding capacity in soil amended with CM. Plants treated with inorganic fertilizer produced the greatest number of fancy fruit, but also produced a low number of U.S. No. 1 fruit (Fig. 2). Inorganic fertilizer also produced the greatest number of U.S. No. 2 fruit compared to HM or SS treatments (Fig. 3, upper graph). Soil amended with vermi-compost produced a significant number of culls (Fig. 3, lower graph). Growers using animal manure that is not properly composted should adhere to the recommendation that there be 130 days between manure application and crop harvest.

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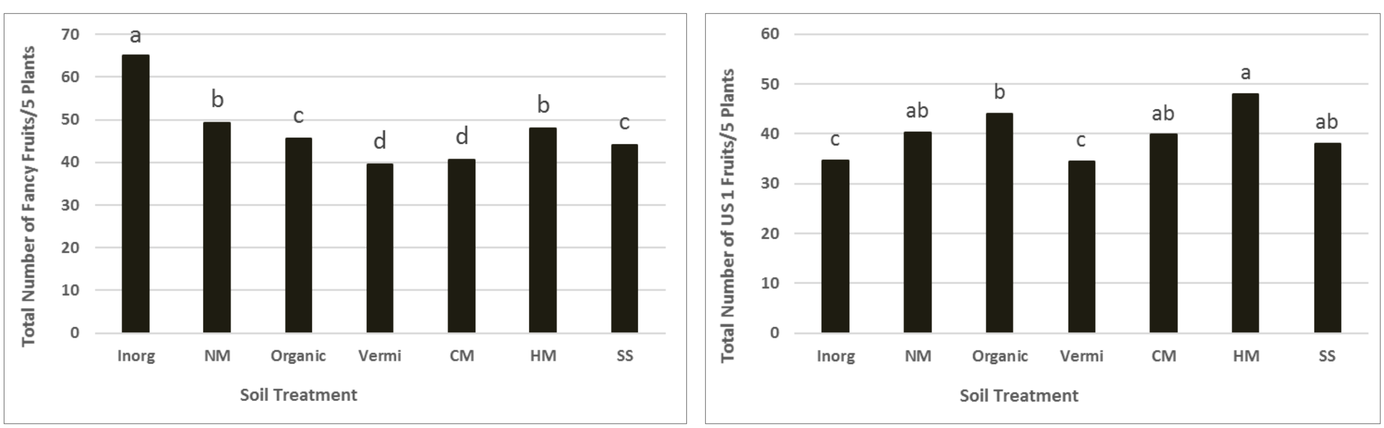

Figure 2. Number of Fancy eggplant fruits (left graph) and U.S. No. 1 fruits (right graph) from plants grown under seven soil management practices: inorganic fertilizer, no-mulch (NM), organic fertilizer, vermi-compost, chicken manure (CM), horse manure (HM), and sewage sludge (SS). Bars accompanied by different letter(s) in each graph indicate significant differences (P < 0.05) using Duncan's multiple range test.

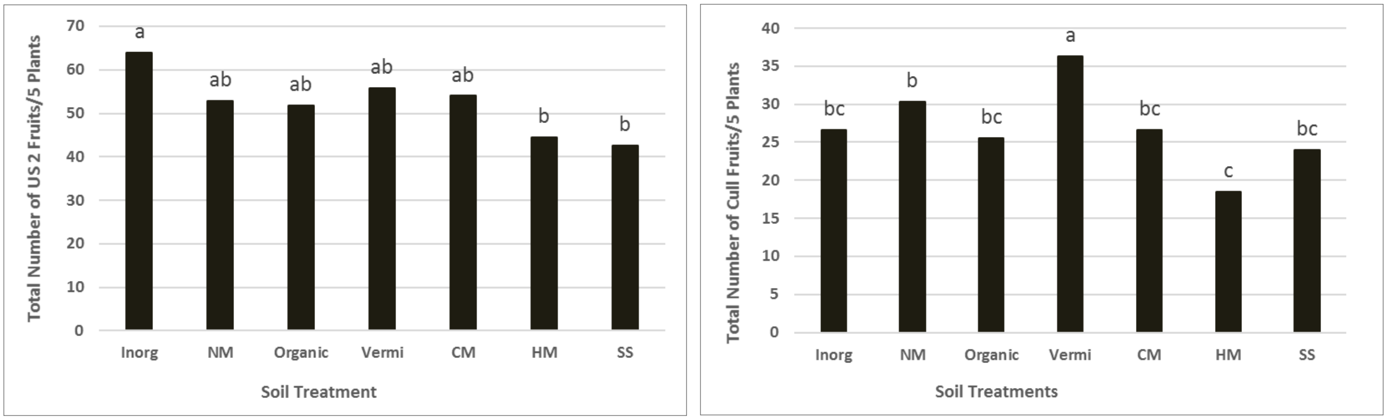

Figure 3. Number of U.S. No. 2 fruits (left graph) and cull fruits (right graph) from plants grown under seven soil management practices: inorganic fertilizer, no-mulch (NM), organic fertilizer, vermi-compost, chicken manure (CM), horse manure (HM), and sewage sludge (SS). Bars accompanied by different letter(s) in each graph indicate significant differences (P < 0.05) using Duncan's multiple range test.

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Impact of Three Alltech Formulations on Two Soil Enzymes, Hot Pepper Plant Size, and Fruit Composition

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Introduction

Soil-Set® (a soil amendment that contains natural enzymatic compounds and balanced nutrients), Grain-Set® (a foliar fertilizer that supplies Mn, S, and Zn to growing plants), and Liqui-Plex® Bonder WP (a foliar fertilizer that contains minerals and amino acids) formulations are products of Alltech Crop Science (Nicholasville, KY) recommended for use in growing vegetables (Antonious 2018). We investigated the impact of these three formulations on growing pepper, *Capsicum annuum* var. Georgia Flame under field conditions. The objectives of this investigation were to: 1) Assess the impact of three organic formulations (Soil-Set, Grain-Set, and Liqui-Plex) on two soil enzymes (urease and invertase). 2) Study the impact of these three formulations on pepper fruit antioxidants (vitamin C, β-carotene, total phenols), and soluble sugars content. 3) Assess the impact of the three formulations on the overall plant morphological characteristics (shoot height, root length, and plant volume).

Materials and Methods

A field study was designed at KSU HR Benson Research and Demonstration Farm on a silty-loam soil. Sixteen field plots of 4 ft wide and 30 ft long (120 sq ft each) were used in a four randomized complete block design (RCBD) with four soil treatments (Soil-Set, Grain-Set, Liqui-Plex, and control plots) replicated four times with two border plots (one at each side of the field study). Each block was divided into the following four treatments: 1) Control (untreated soil and untreated plants), 2) Soil-Set®, applied at 32 oz per acre at planting; 3) Grain-Set®, applied at 8 oz per acre at vegetative stage, and 4) Liqui-Plex® Bonder WP, applied at 16 oz per acre at vegetative stage. The soil was planted with 52 day old seedlings of hot pepper, *Capsicum annuum* var. Georgia Flame on June 2, 2017, and drip-irrigated as needed. Soil-Set®, Grain-Set®, and Liqui-Plex® Formulations (Fig. 1) were obtained from Alltech Crop Science (Nicholasville, KY). Soil-Set® was sprayed on June 2 and Grain-Set® and Liqui-Plex® (foliar fertilizers) were sprayed on July 7 and July 11, 2017. At harvest, soil enzymes (urease and invertase), pepper fruit yield, number of ripe fruits, fruit antioxidants content, plant length and width were measured and statistically analyzed using ANOVA procedure and the means compared using Duncan's test for mean comparisons.

Table 1. Overall impact of Liqui-Plex, Soil-Set, and Grain-Set on hot pepper, *Capsicum annuum* var. Georgia Flame on soil urease and invertase activity.

Treatment	Urease Activity (µg Ammonia released g^{-1} dry soil)	Invertase Activity (µg glucose released g^{-1} dry soil)
Liqui-Plex	137.4 a	15096 a
Control	145.5 a	14350 a
Soil-Set	142.1 a	16641 a
Grain-Set	155.7 a	15148 a

Each value in the table is an average of 12 replicates. Values accompanied with the same letter in each column are not significantly different (P> 0.05).

Table 2. Overall impact of three harvests on hot pepper, *Capsicum annuum* var. Georgia Flame fruit composition expressed as µg g-1 fresh fruits, regardless of soil treatment.

Harvest	β-carotene	Vitamin C	Total Phenols	Soluble Sugars
1	694.9 b	147.8 b	809.5 c	4,693.4 b
2	841.4 ab	188.5 a	1085.8 a	6,848.3 a
3	972.3 a	174.4 a	984. 9 b	6,805.0 a

Each value in the table is an average of 12 replicates. Values accompanied with the same letter in each column are not significantly different (P> 0.05).

Table 3. Overall impact of three Alltech formulations on hot pepper, *Capsicum annuum* var. Georgia Flame fruit composition expressed as µg g-1 fresh fruits, regardless of soil treatment.

Harvest	β-carotene	Vitamin C	Total Phenols	Soluble Sugars
Liqui-Plex	44.9 a	175.4 a	954.4 b	6048.3 a
Control	50.1 a	163.0 a	951.4 b	6046.7 a
Soil-Set	45.0 a	176.0 a	937.0 b	5947.4 a
Grain-Set	48.1 a	166.4 a	997.6 a	6299.7 a

Each value in the table is an average of 12 replicates. Values accompanied with the same letter in each column are not significantly different (P> 0.05).

Table 4. Impact of three Alltech formulations on hot pepper, *Capsicum annuum* var. Georgia Flame plant characteristics.

Treatment	Plant Height, (inches)	Root Weight, (g)	Root Length, (cm)	Plant Size, ($inches^3$)
Liqui-Plex	26.08 a	56.87 a	31.96 a	4845 a
Control	22.16 b	38.33 b	32.84 a	3819 ab
Soil-Set	24.25 ab	50.50 ab	31.00 a	3861 ab
Grain-Set	22.58 b	50.92 ab	28.95 a	3554 b

Each value in the table is an average of 12 replicates. Values accompanied with the same letter in each column are not significantly different (P> 0.05).

Soil Urease and Invertase Analysis

Soil samples were collected from the top 15 cm of each plot before treatment (16 samples) to establish soil enzymes baseline data. After Soil-Set, Grain-Set, and Liqui-Plex applications, soil samples were also collected from each plot between planting and harvest (16 plots x 4 post-treatment sampling dates=64 samples) using a soil core sampler equipped with a plastic liner tube (Clements Associates, Newton, IA) of 2.5 cm inner diameter for measuring soil urease and invertase activity during the growing season.

For determination of urease activity, 10 mL of 0.1 M phosphate buffer (pH 6.7) was added to a five g soil sample in a 50 mL volumetric flask. The flasks were kept in a water bath at 30°C for 1 h to allow the soil temperature to equilibrate and the procedure was completed as described by Antonious, 2016. Urease activity was expressed as mg NH_4-N released per g dried soil during the 1h incubation at 30°C. Invertase activity in soil was estimated by the method described by Balasubramanian et al. Invertase activity was expressed as µg glucose g^{-1} dry soil.

Analysis of Antioxidants in Pepper Fruits

At harvest, ten ripe pepper fruits collected from each treatment (Fig. 2) were cut into small pieces. Representative subsamples (30 g) were blended at high speed with 100 mL of acetone for 2 minutes in dim light to extract and quantify β-carotene according to the methods described by Antonious, 2014. Ascorbic acid extraction was carried out by blending 20

Figure 1. Alltech® Crop Science products used for growing hot pepper, *Capsicum annuum* var. Georgia Flame at KSU H.R. Benson Research and Demonstration Farm (Franklin County, KY).

g of chopped fruits with 100 mL of 0.4% (w/v) oxalic acid solution, and determined by the potassium ferricyanide method (Hashmi, 1973). To determine the degree of fruit sweetness, soluble sugars were extracted from pepper fruits with 80% ethanol and quantified colorimetrically. Representative fruit samples (20 g) were blended with 150 mL of ethanol to extract phenols. Homogenates were filtered through Whatman No. 1 filter paper and one mL aliquots of filtrates were used for determination of total phenols using a standard calibration curve of chlorogenic acid.

Pepper Yield and Fruit Quality Characteristics

At harvest, pepper fruit yield in kg acre $^{-1}$ and fruit number were recorded for each treatment. Fruit composition and plant morphological characteristics were statistically analyzed using analysis of variance.

Pepper Plant Size

Considering that a pepper plant is shaped like a cone, we measured the plant volume as:

V=1/3 * 3.14 * r^2 * h, where v is the plant volume, r is the plant radius, and h is the plant height.

Results and Discussion

No significant differences were found in soil urease and invertase activity among the four soil treatments investigated (Table 1). Table 2 revealed that fruits collected at Harvest 3 contained greater β-carotene, vitamin C, total phenols, and soluble sugars compared to fruits collected at Harvest 1. Whereas, only total phenols in fruits of plants sprayed with Grain-Set formulation were significantly higher than other treatments (Table 3).

Overall, three harvest results revealed that Liqui-Plex® produced the greatest yield and greatest number of ripe fruits (Fig. 3). Results also revealed that pepper fruits obtained from this study were consistent in color and free of noticeable defects. In addition, plants sprayed with Liqui-Plex® formulation were greater ($P < 0.05$) in size (4,845 inches^3) compared to plants sprayed with Grain-Set® formulation (3,554 inches^3) indicating a significant increase in plant shoot volume due to Liqui-Plex® application (Table 4).

Figure 2. Hot pepper, *Capsicum annuum* var. Georgia Flame fruits grown with Liqui-Plex Crop Science organic products at KSU H.R. Benson Research and Demonstration Farm.

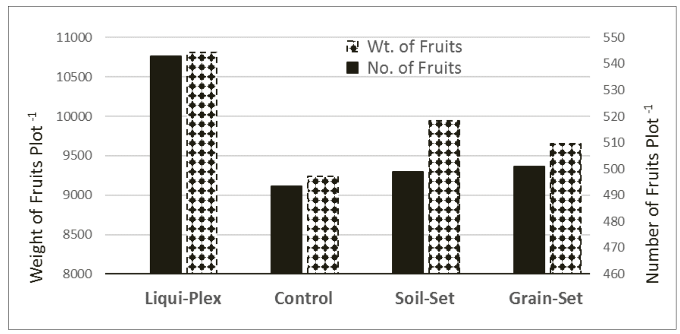

Figure 3. Overall impact of Liqui-Plex, Soil-Set, and Grain-Set on hot pepper, *Capsicum annuum* var. Georgia Flame yield and number of fruits of plants grown at KSU HR Benson Research and Demonstration Farm (Franklin County, KY) over three harvests. Statistical analysis was carried out among soil treatments. Values accompanied by the same letter are not significantly different (P> 0.05) using SAS procedure.

Acknowledgments

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Phenolic Content of Fruit and Leaves of Interspecific Hybrid Tomatoes

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Introduction

Tomato, *Solanum lycopersicum*, is one of the most produced vegetables grown worldwide. In 2006 more than 100 million tons were produced (http://faostat.fao.org). China, United States, and Turkey are the three main production areas in the world. Tomato consumption is increasing because of increasing human population around the world, and it significantly varies per capita among countries. Phenolic compounds such as flavonoids, phenolic acids, and tannins are ubiquitous in plants and are of considerable interest due to their antioxidant properties, one of the major groups of bioactive components and secondary metabolites of dietary phytochemicals found in fruits, vegetables and grains. Besides lycopene, the red pigment in the fruit, tomato also contains several phenolic acids that can provide an essential part of the human diet and act as antioxidants. Phenolics may also be involved in plant growth and reproduction and may provide resistance against pathogens.

Phenolic components have been evaluated in fruit of tomato varieties from different areas of Mauritius. Total phenolic components have been extensively reported in cultivated tomato. However, phenolic content in fruit and leaves of interspecific hybrid tomatoes has not been evaluated. The objective of this experiment was to estimate total phenolic contents in leaves and fruit of interspecific hybrid tomato compared to commonly cultivated tomato.

Material and Methods

Plant Materials

The experiment was conducted in spring and summer, 2018 at the Horticulture Department, University of Kentucky. Plant material used for the experiment consisted of open pollinated tomato varieties, an accession of wild tomato, *S. habrochaites* (LA2329) and interspecific hybrid plants. The interspecific hybrid population originated from crosses between the wild, green fruited, and insect resistant wild tomato relative LA2329 and Zaofen 2. The interspecific hybrid plants used for this experiment were chosen from five BC4F3 families (N122, N152, N166, O35, and O37) and one BC3F3 family (F55). Seeds of all lines were germinated on moist filter paper in an incubator (80°F). After radicle emergence, seed were planted in 72-cell trays containing ProMix BX. Six weeks later, seedlings were transplanted into the field at the Horticulture Research Farm, Lexington, KY. Cultural methods for transplant and field production followed those recommended in ID-36 (http://www2.ca.uky.edu/agcomm/pubs/id/id36/id36.pdf). Samples of leaflet tissue and of fruit used for analysis were taken on 30 August, 2018. Fruits from plants were taken based on ripe fruit availability; and samples of leaf tissue were taken based on variation of the content of a sesquiterpene hydrocarbon, 7-epizingiberene that was classified as high, medium, or low. 7-epizingiberene is associated with insect and spider mite resistance in this tomato breeding population.

Determination of Total Phenol in Leaves and Fruits of Tomato Plants

Samples of leaflet tissue (10 cm^2) for analysis were obtained by collecting the middle part of three leaflets obtained from the third and/or fourth leaf positions of each plant (three replications of each of three plants for each family). The collected tissue was weighed and placed into a scintillation vial (20 mL) containing 4 mL of ethanol: water (80:20, v/v). The vials were shaken for 1 min. using a vortex mixer. After mixing the vials were kept in a refrigerator for 24 hours to reduce oxidation. The total phenolic content was estimated using the Folin Ciocalteau reagent (Sigma-Aldrich®, St. Louis MO, USA) as described by McGrath, Kaluza et al. Total phenolic content was calculated using a tannic acid (Sigma-Aldrich®, St. Louis, Missouri, USA) standard curve.

To determine total phenol content in fruits, fifteen fully ripe fruits from five to seven plants of each family were collected. Fruits were weighed and gently washed with distilled

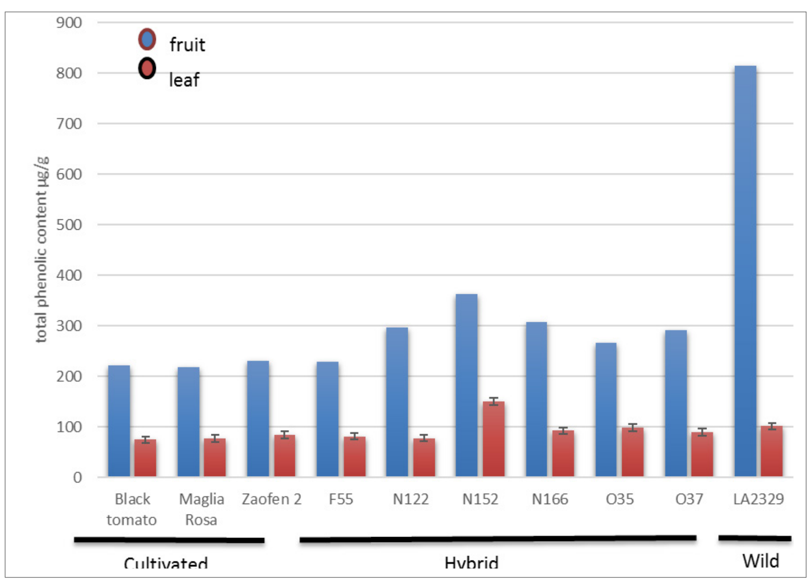

Figure 1. Total phenolic content (µg/g) in leaves (blue bars) and fruit (orange bars) of three tomato cultivars (Black Tomato, Maglia Rosa and Zaofen 2), six BC4F3 families (F55, N122, N152, N166, O35, and O37) and one wild tomato (S. habrochaites – LA2329).

water. Tomato fruits were chopped and then blended for one minute in an Oster® Blender. After that 50 mL of homogenate was filtered through Whatman No. 4 filter paper. Phenolic content was determined in the same fashion as for leaf tissue.

Data Analysis

Statistical Analysis of the data was achieved using Microsoft Excel 2016 and SAS software (version 9.4; SAS Institute, Cary, NC). Pearson correlation coefficients were calculated to evaluate the relationship between total phenolic content of leaves and fruit. Phenolic content of fruit and leaves of hybrid and cultivated tomatoes was subjected to analysis of variance.

Results and Discussion

Total phenolic contents were much higher in fruit than in leaves, ranging between 200-800 µg/g for fruit compared with leaves, which ranged from 75 to 150 µg/g of fresh weight (Fig. 1). For leaves the cultivated tomatoes had lower concentrations of phenolics, compared to the hybrids or the wild accession LA2329. Surprisingly, the highest concentration in leaves was present in the interspecific hybrid family N152 (150 µg/g), which was significantly higher ($P \leq 0.01$) than any of the other genotypes measured, which ranged from 75 to 102 µg/g. For fruit the highest concentration of phenolics was present in the wild accession LA2329 (819 µg/g) and was lowest for the cultivated tomatoes (235±10.0). Concentrations of phenolics in the hybrids were generally intermediate to concentrations in the cultivated and wild tomatoes, ranging from 230 µg/g for the F55 family to 354 µg/g for the N152 family. The average phenolic content of the fruit for all hybrid families was 291 ± 8.2 µg/g suggesting that the phenolic content was somewhat higher in hybrids compared with the cultivated tomatoes. This observation is bolstered by an ANOVA of fruit phenolic concentration for the cultivated and hybrid plants in which the F-test for differences between the hybrids and cultivars was highly significant ($P=0.0002$; 1, 26 df). The interspecific hybrid population is undergoing breeding and selection for trichome characteristics related to arthropod resistance and has not been consciously bred or selected for phenolic content. Based on these preliminary results it appears that there is a large difference in phenolic content of fruit between the wild and cultivated species, the two parents of the interspecific population. Thus, it is not surprising that the phenolic content of fruit from interspecific hybrids was somewhat elevated above that present in the cultivated parent. This experiment provides a snapshot of an inbred population, an F3 resulting from three successive self-pollinations of a relatively advanced backcross generation, a BC3 or BC4. Based on the preliminary results presented here, a more encompassing survey of phenolic content variation in the population, especially in earlier backcross generations could uncover individuals having much higher concentrations of phenolics in their fruit, concentrations more line that observed in the wild parent.

When considering the relationship between phenolic content of leaves and fruit, the correlation between phenolic content of leaves and fruit was positive and mild, $r=0.58$, significant at $P <0.001$ This suggests a possible causal relationship between the phenolic content of leaves and fruit. Perhaps phenolic content of fruits can be predicted from leaf phenolic content.

Conclusion

The current study revealed that the total phenolic content in interspecific hybrid tomatoes was higher than that in open pollinated varieties (*S. lycopersicum*), while in the wild tomato relative, LA 2329, was much higher than varieties or hybrids. The total phenolic content in the fruits and leaves were positively correlated, suggesting future investigation of early selection of phenolic content in the fruit based on phenolic content in the leaf tissue. Additional work needs to be done to verify these results and also to search within the interspecific population for plants that may produce fruit with phenolic concentrations higher than those reported here for the BC4F3 hybrids. These initial results suggest that it may be possible to breed tomatoes with higher phenolic contents, which could perhaps lead to improvement of human diets or in plant disease resistance.

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Appendix A
Sources of Vegetable Seeds

The abbreviations used in this appendix correspond to those listed after the variety names in tables of individual trial reports.

AAS .... All America Selection Trials, 1311 Butterfield Road, Suite 310, Downers Grove, IL 60515
AS/ASG .... Formerly Asgrow Seed Co., now Seminis (see "S" below)
AC.................. Abbott and Cobb Inc., Box 307, Feasterville, PA 19047
AG.................. Agway Inc., P.O. Box 1333, Syracuse, NY 13201
AM................. American Sunmelon, P.O. Box 153, Hinton, OK 73047
AR.................. Aristogenes Inc., 23723 Fargo Road, Parma, ID 83660
AT.................. American Takii Inc., 301 Natividad Road, Salinas, CA 93906
B..................... BHN Seed, Division of Gargiulo Inc., 16750 Bonita Beach Rd., Bonita Springs, FL 34135
BBS................ Baer's Best Seed, 154 Green St., Reading, MA 01867
BC.................. Baker Creek Heirloom Seeds, 2278 Baker Creek Rd., Mansfield, OH 65704
BK.................. Bakker Brothers of Idaho Inc., P.O. Box 1964, Twin Falls, ID 83303
BL................... Burrell Seed Growers, P.O. Box 150, Rocky Ford, CO 81067
BR.................. Bruinsma Seeds B.V., P.O. Box 1463, High River, Alberta, Canada, TOL 1B0
BS................... Bodger Seed Ltd., 1800 North Tyler Ave., South El Monte, CA 91733
BU.................. W. Atlee Burpee & Co., P.O. Box 6929, Philadelphia, PA 19132
BZ.................. Bejo Zaden B.V., 1722 ZG Noordscharwoude, P.O. Box 9, The Netherlands
CA.................. Castle Inc., 190 Mast St., Morgan Hill, CA 95037
CF.................. Cliftons Seed Co., 2586 NC 43 West, Faison, NC 28341
CG.................. Cooks Garden Seed, PO Box C5030 Warminster, PA 18974
CH.................. Alf Christianson, P.O. Box 98, Mt. Vernon, WA 98273
CIRT............... Campbell Inst. for Res. and Tech., P-152 R5 Rd 12, Napoleon, OH 43545
CL.................. Clause Semences Professionnelles, 100 Breen Road, San Juan Bautista, CA 95045
CN.................. Canners Seed Corp., (Nunhems) Lewisville, ID 83431
CR.................. Crookham Co., P.O. Box 520, Caldwell, ID 83605
CS.................. Chesmore Seed Co., P.O. Box 8368, St. Joseph, MO 64508
D.................... Daehnfeldt Inc., P.O. Box 947, Albany, OR 97321
DN................. Denholm Seeds, P.O. Box 1150, Lompoc, CA 93438-1150
DR.................. DeRuiter Seeds Inc., P.O. Box 20228, Columbus, OH 43320
EB................... Ernest Benery, P.O. Box 1127, Muenden, Germany
EV.................. Evergreen Seeds, Evergreen YH Enterprises, P.O. Box 17538, Anaheim, CA 92817
EX.................. Express Seed, 300 Artino Drive, Oberlin, OH 44074
EW .... East/West Seed International Limited, P.O. Box 3, Bang Bua Thong, Nonthaburi 1110, Thailand
EZ................... ENZA Zaden, P.O. Box 7, 1600 AA, Enkhuisen, The Netherlands 02280-15844
FED................ Fedco Seed Co., P.P. Box 520 Waterville, ME, 04903
FM................. Ferry-Morse Seed Co., P.O. Box 4938, Modesto, CA 95352
G.................... German Seeds Inc., Box 398, Smithport, PA 16749-9990
GB.................. Green Barn Seed, 18855 Park Ave., Deephaven, MN 55391
GL.................. Gloeckner, 15 East 26th St., New York, NY 10010
GO................. Goldsmith Seeds Inc., 2280 Hecker Pass Highway, P.O. Box 1349, Gilroy, CA 95020
GU................. Gurney's Seed and Nursery Co., P.O. Box 4178, Greendale, IN 47025-4178
HI................... High Mark Seeds, 5313 Woodrow Ln, Hahira, GA 31632
HL/HOL......... Hollar & Co. Inc., P.O. Box 106, Rocky Ford, CO 81067
H/HM............ Harris Moran Seed Co., 3670 Buffalo Rd., Rochester, NY 14624, Ph: (716) 442-0424
HMS.............. High Mowing Organic Seeds, 76 Quarry Rd., Wlacott, VT 05680
HN................. HungNong Seed America Inc., 3065 Pacheco Pass Hwy., Gilroy, CA 95020
HO................. Holmes Seed Co., 2125-46th St., N.W., Canton, OH 44709
HR.................. Harris Seeds, 60 Saginaw Dr., P.O. Box 22960, Rochester, NY 14692-2960
HS.................. Heirloom Seeds, P O Box 245, W. Elizabeth PA 15088-0245
HZ.................. Hazera Seed, Ltd., P.O.B. 1565, Haifa, Israel
JU................... J. W. Jung Seed Co., 335 High St., Randolf, WI 53957
JS/JSS........... Johnny's Selected Seeds, Foss Hill Road, Albion, MA 04910-9731
KB.................. K&B Development, LLC., 10030 New Avenue, Gilroy, CA 95020
KS................... Krummrey & Sons Inc., P.O. 158, Stockbridge, MI 49285
KY/KU........... Known-You Seed Co., Ltd. 26 Chung Cheng Second Rd., Kaohsiung, Taiwan, R.O.C. 07-2919106
KZ.................. Kitazawa Seed Co., PO Box 13220 Oakland, CA 94661-3220
LI.................... Liberty Seed, P.O. Box 806, New Philadelphia, OH 44663
LSL................. LSL Plant Science, 1200 North El Dorado Place, Suite D-440, Tucson, AZ 85715
MB................. Malmborg's Inc., 5120 N. Lilac Dr., Brooklyn Center, MN 55429
MK................. Mikado Seed Growers Co. Ltd., 1208 Hoshikuki, Chiba City 280, Japan 0472 65-4847
ML .... J. Mollema & Sons Inc., Grand Rapids, MI 49507
MM................ MarketMore Inc., 4305 32nd St. W., Bradenton, FL 34205
MN .... Dr. Dave Davis, U of MN Hort Dept., 305 Alderman Hall, St. Paul, MN 55108
MR................. Martin Rispins & Son Inc., 3332 Ridge Rd., P.O. Box 5, Lansing, IL 60438
MS................. Musser Seed Co. Inc., Twin Falls, ID 83301
MWS............. Midwestern Seed Growers, 10559 Lackman Road, Lenexa, Kansas 66219
NE.................. Neuman Seed Co., 202 E. Main St., P.O. Box 1530, El Centro, CA 92244
NI................... Clark Nicklow, Box 457, Ashland, MA 01721
NU................. Nunhems (see Canners Seed Corp.)
NS.................. New England Seed Co., 3580 Main St., Hartford, CT 06120
NZ.................. Nickerson-Zwaan, P.O. Box 19, 2990 AA Barendrecht, The Netherlands

OE.................. Ohlsens-Enke, NY Munkegard, DK-2630, Taastrup, Denmark
ON.................. Osbourne Seed Co., 2428 Old Hwy 99 South Road Mount Vernon, WA 98273
OR.................. Origene Seeds, P.O. Box 699, Rehovet, Israel
OS.................. Outstanding Seed Co., 354 Center Grange Road, Monaca PA 15061
OLS................ L.L. Olds Seed Co., P.O. Box 7790, Madison, WI 53707-7790
OT.................. Orsetti Seed Co., P.O. Box 2350, Hollister, CA 95024-2350
P..................... Pacific Seed Production Co., P.O. Box 947, Albany, OR 97321
PA/PK............ Park Seed Co., 1 Parkton Ave., Greenwood, SC 29647-0002
PARA............. Paragon Seed Inc., P.O. Box 1906, Salinas CA, 93091
PE.................. Peter-Edward Seed Co. Inc., 302 South Center St., Eustis, FL 32726
PF.................. Pace Foods, P.O. Box 9200, Paris, TX 75460
PG.................. The Pepper Gal, P.O. Box 23006, Ft. Lauderdale, FL 33307-3006
PL.................. Pure Line Seeds Inc., Box 8866, Moscow, ID
PM................. Pan American Seed Company, P.O. Box 438, West Chicago, IL 60185
PR.................. Pepper Research Inc., 980 SE 4 St., Belle Glade, FL 33430
PT.................. Pinetree Garden Seeds, P.O. Box 300, New Gloucester, ME 04260
R..................... Reed's Seeds, R.D. #2, Virgil Road, S. Cortland, NY 13045
RB/ROB......... Robson Seed Farms, P.O. Box 270, Hall, NY 14463
RC.................. Rio Colorado Seeds Inc., 47801 Gila Ridge Rd., Yuma, AZ 85365
RE.................. Reimer Seed Co., PO Box 236, Mt. Holly, NC 28120
RG.................. Rogers Seed Co., P.O. Box 4727, Boise, ID 83711-4727
RI/RIS............ Rispens Seeds Inc., 3332 Ridge Rd., P.O. Box 5, Lansing, IL 60438
RS.................. Royal Sluis, 1293 Harkins Road, Salinas, CA 93901
RU/RP/RUP.. Rupp Seeds Inc., 17919 Co. Rd. B, Wauseon, OH 43567
S..................... Seminis Inc. (may include former Asgrow and Peto cultivars), 2700 Camino del Sol, Oxnard, CA 93030-7967
SE.................. Southern Exposure Seed Exchange, P.O. Box 460Mineral, VA 23117
SHUM........... Shumway Seed Co., 334 W. Stroud St. Randolph, WI 53956
SI/SG............ Siegers Seed Co., 8265 Felch St., Zeeland, MI 49464-9503
SIT.................. Seeds From Italy, P.O. Box 149, Winchester, MA 01890
SK.................. Sakata Seed America Inc., P.O. Box 880, Morgan Hill, CA 95038
SN.................. Snow Seed Co., 21855 Rosehart Way, Salinas, CA 93980
SO.................. Southwestern Seeds, 5023 Hammock Trail, Lake Park, GA 31636
SOC............... Seeds of Change, Sante Fe, NM
SST................ Southern States, 6606 W. Broad St., Richmond, VA 23230
ST.................. Stokes Seeds Inc., 737 Main St., Box 548, Buffalo, NY 14240
SU/SS............ Sunseeds, 18640 Sutter Blvd., P.O. Box 2078, Morgan Hill, CA 95038
SV.................. Seed Savers Exchange, 3094 North Winn Rd., Decorah, IA 52101
SW................. Seedway Inc., 1225 Zeager Rd., Elizabethtown, PA 17022
SY.................. Syngenta/Rogers, 600 North Armstrong Place (83704), P.O. Box 4188, Boise, ID 83711-4188
T/TR.............. Territorial Seed Company, P.O. Box 158, Cottage Grove, OR 97424
TGS............... Tomato Growers Supply Co., P.O. Box 2237, Ft. Myers, FL 33902
TS.................. Tokita Seed Company, Ltd., Nakagawa, Omiya-shi, Saitama-ken 300, Japan
TT.................. Totally Tomatoes, P.O. Box 1626, Augusta, GA 30903
TW................. Twilley Seeds Co. Inc., P.O. Box 65, Trevose, PA 19047
UA.................. US Agriseeds, San Luis Obispo, CA 93401.
UG................. United Genetics, 8000 Fairview Road, Hollister, CA 95023
US.................. US Seedless, 12812 Westbrook Dr., Fairfax, VA 22030
V..................... Vesey's Seed Limited, York, Prince Edward Island, Canada
VL.................. Vilmorin Inc., 6104 Yorkshire Ter., Bethesda, MD 20814
VS.................. Vaughans Seed Co., 5300 Katrine Ave., Downers Grove, IL 60515-4095
VTR................ VTR Seeds, P.O. Box 2392, Hollister, CA 95024
WI.................. Willhite Seed Co., P.O. Box 23, Poolville, TX 76076
WP................. Woodpraire Farms, 49 Kinney Road, Bridgewater, ME 04735
ZR.................. Zeraim Seed Growers Company Ltd., P.O. Box 103, Gedera 70 700, Israel

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