PR-798

University of Kentucky
College of Agriculture,
Food and Environment
Agricultural Experiment Station

Fruit and Vegetable

2021 ANNUAL RESEARCH REPORT

Agricultural Experiment Station | Kentucky Tobacco Research and Development Center | Veterinary Diagnostic Laboratory | Division of Regulatory Services | Research and Education Center
Robinson Forest | Robinson Center for Appalachian Resource Sustainability | University of Kentucky Superfund Research Center | Equine Programs

2021 Fruit and Vegetable Crops Research Report

Edited by Rachel Rudolph

AUTHORS:

University of Kentucky

Horticulture

Faculty	Winston Dunwell Krista Jacobsen Rachel Rudolph John Strang (*Emeritus*) Shawn Wright
Area Extension Associates	Daniel Becker Chris Smigell
Professional Staff	Ryan Lark Wyatt Lucas (intern) Sean Lynch David Neace Ginny Travis Dwight Wolfe

Entomology

Faculty	Ric Bessin Raul Villanueva
Professional Staff	Zenaida Viloria

Plant Pathology

Faculty	Nicole Gauthier
Professional Staff	Edward Dixon
Students	Henry Smith

Kentucky State University

Faculty	George F. Antonious Kirk Pomper
Professional Staff	Sheri Crabtree Jeremiah Lowe Rance Paxton Eric Turley

University of Arkansas

Faculty	John Clark

University of Kufa, Iraq

Faculty	Mohammad H. Dawood

Cover: 'Marciano' lettuce grown at the University of Kentucky College of Agriculture, Food and Environment's Horticulture Research Farm in Lexington, KY.

Photographer: Rachel Rudolph

Contents

Tree Fruit

Small Fruit and Grapes

Vegetables

Acknowledgments

Grants from the Agricultural Development Board through the Kentucky Horticulture Council have allowed an expansion of the field research and demonstration program to meet the informational and educational needs of our growing vegetable and fruit industries. The editors would also like to thank the Kentucky Vegetable Growers Association and the Kentucky State Horticulture Society for providing funds to cover the costs of printing in 2021.

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.

The 2021 Fruit and Vegetable Crops Research Program

Rachel Rudolph, Horticulture, University of Kentucky

The 2021 Fruit and Vegetable Crops research report includes results from 12 different projects. The majority of projects were conducted on research farms, but a few were conducted on commercial farms with the assistance of grower-cooperators. We are truly grateful to the growers who invest their time, energy, and land in supporting research. Their contributions help other growers, and that is of immeasurable value. Research was conducted by University of Kentucky faculty and staff from the horticulture, plant pathology, and entomology departments, as well as faculty and staff of Kentucky State University.

The fruit trials in this year's publication include a pawpaw variety trial, a blackberry variety trial, evaluation of the effect of container and substrate composition on the productivity and growth of blueberry, rootstock effects on apple tree growth and yield, and plant soil and foliar analyses of blueberry and apple across Kentucky. The vegetable trials include kale, lettuce, and watermelon variety trials. Evaluation of varieties is a continuing necessity and allows us to provide current information to growers across the state about the production and performance of various crops. The vegetable variety trial results are the basis for updating the recommendations in our Vegetable Production Guide for Commercial Growers (ID-36), which has been updated this year and is now available online. 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. Additional research in this year's report addresses high tunnel soil nutrient leaching, insecticide efficacy against ambrosia beetle, determining the cause of grapevine trunk disease, and the impact of biochar and animal manure on turnips. Below are guidelines for interpreting the results of our projects.

Our Yields vs. Your Yields

Yields reported in variety trial results are often extrapolated from small plots. Depending on the crop, individual plots range from one to 200 plants. Sometimes our yields are reported as is, and at other times, they are calculated by multiplying the yields in these small plots by correction factors to estimate per-acre yield. For example, if 4200 tomato plants can be planted per acre (assuming in-row spacing of 18 in) 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 for larger plots or entire acreages. 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 the same. For example, if tomato variety 1 has an average yield of 2000 boxes per acre, and tomato variety 2 yields 2300 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 1800, 1900, 2200, and 2100 boxes per acre. The average yield would then be 2000 boxes per acre. Tomato variety 2 may have had four plots with yields of 1700, 2500, 2800, and 2200 boxes per acre. The four plots together would average 2300 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 also yield consistently. Tomato variety 2 may have had yields similar to variety 1, but it also had much greater variation. Therefore, all other things being equal, tomato variety 1 may be a better choice due to less variable yield 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 $P \leq 0.05$, 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 $P \leq 0.05$ is considered standard practice for agricultural research. This approach may be confusing, but without statistics, our results would not be useful. Using statistics ensures that we can make more accurate recommendations for growers.

Plant Tissue and Soil Analysis Results from Kentucky Apple Orchards from 2018 through 2019

John Strang, Chris Smigell, and Daniel Becker, Horticulture, University of Kentucky

Soil and foliar tissue samples were collected during the periods from 15 July to 15 Aug. in 2018 and 2019 from 31 Kentucky commercial apple [*Malus x sylvestris (L) Mill. var domestica (Borkh.) Mansf*] orchards as part of our Apple Integrated Pest Management (IPM) program to evaluate apple tree nutritional status across the state. A similar evaluation was conducted on Kentucky apple orchard foliar samples collected between 1980 and 1997, providing the opportunity to evaluate the status of orchards over time. It is important to collect both soil and foliar samples as soil pH and other factors may increase or decrease nutrient uptake even when a soil sample indicates sufficient nutrient availability. It is very important to adjust orchard soil pH, phosphorus (P), potassium (K), and magnesium (Mg) levels prior to establishing an orchard as it is very difficult to adjust these after trees are established. The optimum soil pH range is 6.0–6.4, while the sufficiency range for P is 35–70 lb/acre, K is 200–300 lb/acre, and Mg is 61–120 lb/acre (Ritchey and McGrath, 2020).

Materials and Methods

At each farm, soil and foliar tissue samples were collected from a row of 10 trees of one cultivar between 15 July and 15 Aug. (Strang and Wright, 2011). Two composite soil samples, each consisting of eight soil probe core samples, were collected. The first composite sample was collected from 0–8 in soil depth and the second from 8–16 in depth. All samples were collected halfway between trees in the row. Soil samples were analyzed at the University of Kentucky Soil Testing Laboratory in either Lexington, KY, or Princeton, KY. A tissue sample of 60 leaves was also collected. Two leaves were selected from the midportion of the current season's growth at eye level from 30 shoots of the 10 trees. Leaves were selected from trees that appeared healthy. Leaves were washed in water containing a drop of dishwashing detergent, rinsed quickly, and air-dried before being sent for analysis at Waters Agricultural Laboratories, Inc. (Owensboro, KY).

Results and Discussion

Soil Sample Results

Soil samples were analyzed for pH, P, K, and Mg. At the 0–8 in depth, 10 samples were below the optimum pH range of 6.0–6.4, 20 were within this range, and one was above (Table 1). Eleven samples tested as low/deficient in P (below 35 lb/acre), seven samples were sufficient, and 13 had high/excessive P levels (above 70 lb/acre). Twelve samples had low/deficient K (below 200 lb/acre), 11 were sufficient, and eight had high/excessive K levels (above 300 lb/acre). None of the samples were low/deficient in Mg (below 60 lb/acre), while three were sufficient and 28 had high/excessive levels (above 120 lb/acre).

Soil samples at the 8–16 in depth (Table 2) showed 22 with a low or deficient pH, eight in the sufficient range, and one with a high pH. Nineteen samples had a low/deficient P level, while five were sufficient and seven were determined to be in the high/excessive range. Twenty samples were low/deficient in K, nine were sufficient, and only two were high/excessive. None tested low for Mg, while five were sufficient and 26 were in the high/excessive range. In general, at the lower soil depth the soil pH declined, and more nutrients were in the deficient/low range.

Tissue Sample Results

The majority of the 31 tissue samples collected during 2018–2019 were sufficient in all elements except K and zinc (Zn) (Table 3, Table 4). There were 27 cases where nutrients were deficient and 64 cases where nutrients were low. Zinc was found to be excessive (above 200 ppm) in eight samples and manganese (Mn) was found to be excessive (above 140 ppm in two samples.

An examination of the major elements shows that nitrogen (N) was not deficient in any tissue samples and high in seven. Normal or sufficient N levels are 1.80%–2.80% dry matter. Thus, N levels have been well maintained by Kentucky apple

Table 1. Number of soil samples, 0-8 in depth, collected from apple orchards across Kentucky and their nutrient level ranking, 2018-2019.

Nutrient level ranking	pH	Nutrient analyzed		
		P	K	Mg
Deficient	1	6	1	0
Low	9	5	11	0
Sufficient	20	7	11	3
High	1	7	5	16
Excessive	0	6	3	12

P = phosphorus, K = potassium, Mg = magnesium

Table 2. Number of soil samples, 8-16 in depth, collected from apple orchards across Kentucky and their nutrient level ranking, 2018-2019.

Nutrient level ranking	pH	Nutrient analyzed		
		P	K	Mg
Deficient	2	12	2	0
Low	20	7	18	0
Sufficient	8	5	9	5
High	1	3	1	13
Excessive	0	4	1	13

P = phosphorus, K = potassium, Mg = magnesium

Table 3. Number of Kentucky apple orchard foliar samples showing the nutrient level ranking for each nutrient and percentage of samples ranked as low or deficient, 2018-2019.

Nutrient level ranking	Nutrient analyzed										
	N	P	K	Mg	Ca	S	B	Zn	Mn	Fe	Cu
Deficient	0	0	10	1	4	0	2	11	0	0	0
Low	0	12	6	6	5	10	6	5	1	6	4
Sufficient	24	19	15	24	22	21	23	6	26	25	27
High	7	0	0	0	0	0	0	1	2	0	0
Excessive	0	0	0	0	0	0	0	8	2	0	0
Samples low or deficient (%)[z]	0	39	51	23	29	32	26	51	3	19	13

N = nitrogen, P = phosphorus, K = potassium, Mg = magnesium, Ca = calcium, S = sulfur, B = boron, Zn = zinc, Mn = manganese, Fe = iron, Cu = copper

[z] 31 total samples collected.

Table 4. Nutritional ranges for interpreting apple leaf analysis values[z].

	Dry matter (%)			
Nutrient	**Deficient**	**Low**	**Normal**	**High**
Nitrogen	< 1.60	< 1.80	1.80-2.80	> 2.80
Phosphorus	< 0.11	< 0.15	0.15-0.30	> 0.30
Potassium	< 0.70	< 1.20	1.20-2.00	> 2.00
Calcium	< 0.31	< 1.30	1.30-3.00	> 3.00
Sulfur[y]	< 0.1	< 0.16	0.16-0.40	> 0.40
Magnesium	< 0.03	< 0.20	0.20-0.40	> 0.40
Nutrient	**ppm**			
Manganese	< 5	< 22	22-140	> 140
Iron	< 25	< 40	40-100	> 100
Copper	< 4	< 6	6-25	> 25
Boron	< 11	< 35	35-80	> 80
Zinc	< 6	< 20	20-200	> 200

[z] Penn State Tree Fruit Production Guide, 2016-2017
[y] Waters Agricultural Laboratories, Inc.

Table 5. Comparison of 0-8 in soil and corresponding foliar test results for phosphorus (P), potassium (K), and magnesium (Mg) for 31 Kentucky apple orchards, 2018-2019.

	Equal nutrient levels in soil and foliar samples		Different levels between soil and foliar samples		
			Comparison		
Nutrient	**Level[z]**	**No. of orchards**	**Soil**	**Foliar**	**No. of orchards**
Phosphorus	low	6	low	sufficient	5
	sufficient	4	low	high	0
	high	0	sufficient	low	3
			sufficient	high	0
			high	low	3
			high	sufficient	10
Potassium	low	9	low	sufficient	3
	sufficient	6	low	high	0
	high	0	sufficient	low	5
			sufficient	high	0
			high	low	2
			high	sufficient	6
Magnesium	low	0	low	sufficient	0
	sufficient	1	low	high	0
	high	0	sufficient	low	2
			sufficient	high	0
			high	low	5
			high	sufficient	23

[z] Nutrient rankings have been simplified for comparison purposes. Foliar nutrient levels that were rated as low or as deficient have been combined into the "low" category and analyses rated as high or as excessive have been combined into the "high" category.

growers, as N needs to be applied annually where soil organic matter does not provide enough. Phosphorus was sufficient in 19 orchards and low in 12, while K was sufficient in 15, low in six, and deficient in 10. Magnesium was sufficient in 24 orchards, low in six, and deficient in one. Calcium (Ca) was sufficient in 22 plantings, low in five, and deficient in four. Sulfur (S) was sufficient in 21 orchards and low in 10.

Micronutrient analyses show that boron (B) was sufficient in 23 orchards, low in six, and deficient in two. Zinc was sufficient in six plantings, low in five, and deficient in 11 Manganese was sufficient in 26 sites, and low in one. Iron (Fe) was sufficient in 25 orchards and low in six, while copper (Cu) was sufficient in 27 plantings and deficient in four.

If the 0–8 in soil and foliar test results for P, K and Mg are compared, quite a disparity is evident (Table 5). Comparing just the soil and tissue P levels shows that the 31 orchards ranged as follows:

- six where the soil and foliar analyses agreed that the soil level for P was low and the tissue sample level was low
- four where samples agreed that the soil P was sufficient and the tissue levels were sufficient
- five where the soil level tested as low and the foliar level tested sufficient for P
- three where the soil tested sufficient for P and the foliar level tested low
- three where the soil P level tested high and the foliar level tested low
- 10 where the soil P level tested high and the foliar level tested sufficient

Thus, in many cases the soil test levels for P, K, and Mg do not reflect what the plant is actually taking up in the foliage, substantiating the need for foliar analyses.

A historical perspective is provided on Kentucky apple orchard nutrition (Table 6). It should be noted that many of the orchard samples collected between 1980 and 1997 are not from the same orchards that were evaluated in 2018 and 2019. None of the samples in the current evaluation were rated low or deficient in N (Table 3), while 18% of the 1980–1997 samples were low in N. Fewer orchards showed deficient or low foliar B and Cu levels from 2018–2019 than from 1980–1997. Conversely, the percentages of low foliar P, K, Mg, Ca, Zn, Mn, and Fe levels found in orchards in 2018–2019 were higher than were found in the orchards evaluated between 1980 and 1997. Foliar S levels were not measured in the 1980 through 1997 evaluations, and the 2018–2019 evaluation indicates that 32% of Kentucky orchards have slightly low S levels. Aluminum is not a required nutrient for plant growth and was inadvertently omitted from the 2018–2019 evaluation. This element can be toxic to the trees at high levels, and the 1980 through 1997 samples show that this should be a Kentucky grower concern. Overall, the trend indicates that Kentucky orchards have improved their N, B, and Cu foliar nutrition, but there has been a reduction in P, K, Mg, Ca, Zn, Mn, and Fe foliar nutrients.

This study shows that many Kentucky orchards have multiple nutrient deficiencies (Table 7). Only two out of the 31 orchards showed sufficient levels for all nutrients, while 43% of the orchards had four or more elements that were low or deficient. Plantings with multiple low foliar nutrients tend to be in central Kentucky.

The period between 15 July and 15 Aug. is a busy one for commercial apple growers. Consequently, tissue testing is rarely done. The 31 analyses in 2018 and 2019 show that growers need to pay more attention to their orchard nutritional status. The evaluation shows that they can improve their tree performance and fruit quality by collecting soil and tissue samples every several years and adjusting their orchard nutrition program according to the results of those analyses. Overall, N, Mn, Cu, Fe, and Mg foliar levels were least likely to be low or deficient, while Zn, K, P, and Ca levels tended to be low or deficient

Table 6. Number of foliar samples (out of 74 total) showing the nutrient level ranking for each nutrient, along with the percentage of samples ranked as low, for samples collected from Kentucky apple orchards between 1980 and 1997.

Nutrient level ranking	Nutrient analyzed^z											
	N	P	K	Mg	Ca	S^y	B	Zn	Mn	Fe	Cu	Al
Low	13	14	13	2	11	-	27	16	0	9	15	2
Sufficient	53	60	45	70	59	-	46	35	59	65	58	48
High	8	0	16	2	4	-	1	23	15	0	1	24
Samples low (%)	18	23	18	3	15	-	36	22	0	12	20	3

[z] N = nitrogen, P = phosphorus, K = potassium, Mg = magnesium, Ca = calcium, S = sulfur, B = boron, Zn = zinc, Mn = manganese, Fe = iron, Cu = copper.

[y] Sulfur was not analyzed 1980-1997.

Table 7. Nutrient status of foliar samples and the geographical distribution for 31 sampled Kentucky apple orchards, 2018-2019.

Nutrient status in samples	No. of foliar samples	Kentucky orchard distribution
All nutrients sufficient or higher	2	1 west, 1 central
1 nutrient low/deficient	5	1 west, 4 central
2 nutrients low/deficient	5	3 west, 1 central, 1 east
3 nutrients low/deficient	6	2 west, 3 central, 1 east
4 nutrients low/deficient	10	2 west, 8 central
5 or more nutrients low/deficient	3	1 west, 1 central, 1 east

in more orchards (Table 3). In a third of the orchards evaluated, where the soil pH was low or deficient, applying lime to raise the soil pH will make soil nutrients more readily available for plant uptake.

Acknowledgments

Funding for this study was provided by the University of Kentucky IPM Program through a grant from the USDA National Institute of Food and Agriculture Integrated Pest Management Program.

Literature Cited

Krawczyk, G. (ed.). 2016. Penn State tree fruit production guide 2016–2017. Penn State Univ., Univ. Park, Pa. AGRS-045.

Ritchey, E. and J. McGrath (eds.). 2020. 2020-2021 lime and nutrient recommendations. Univ. KY College Agr. Food Environ., Lexington, KY. AGR-1. 19 Oct. 2021. <http://www2.ca.uky.edu/agcomm/pubs/agr/agr1/agr1.pdf>

Strang, J. and S. Wright. 2011. Fruit crop tissue analysis. Univ. KY College Agr. Food Environ., Lexington, KY. HortFact-3001. 19 Oct. 2021. <https://www.uky.edu/hort/sites/www.uky.edu.hort/files/documents/foliar.pdf>

Rootstock Effects on Apple Tree Growth and Yield

Dwight Wolfe, Daniel Becker, and Ginny Travis, Horticulture, University of Kentucky

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 income per acre 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. 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 grower cooperators. Kentucky's NC-140 rootstock plantings are located at the University of Kentucky Research and Education Center (UKREC) at Princeton, KY. All data from these trials are analyzed using SAS v.9.4 (SAS Institute).

The 2010 Apple Rootstock Trial Bitter Pit Evaluation

The 2010 apple rootstock trial consisted of 31 different rootstocks with 'Aztec Fuji' as the scion cultivar (Table 1). These were compared in a randomized complete block experimental design in four blocks, with one to three trees per rootstock per block. The trees were planted in Mar. 2010 on a 6 × 15 ft spacing and trained to the tall spindle system. This trial was completed in 2018, and details and a final summary were reported previously (Wolfe, 2018; Wolfe et al., 2019).

From this planting, one tree from each replication (where available) was selected from each of the rootstocks (Table 2) for a follow-up study to evaluate the influence of rootstock on the incidence of bitter pit (Wolfe et al., 2018). A 50-fruit sample was collected at harvest from each of these trees and evaluated for the presence of bitter pit. The sample was then stored in a cooler for approximately 90 days at about 40 °F. The fruit from each sample were then reevaluated for the presence of bitter pit (percentage of fruit in 50-fruit sample). Flesh firmness measurements, total soluble solids (Brix) readings, and blush color ratings (only for 2020 season) were recorded from a subsample of 10 fruit from each 50-fruit sample. This work concluded in Jan. 2021 after testing and evaluating samples in cold storage from the 2020 fall harvest.

The 2019 Apple Rootstock Trial

An apple rootstock trial was planted at the UKREC orchard in Princeton, KY, on 11 Apr. 2019, at a 3 × 13.5 ft spacing using feathered trees from Gold Crown Nursery in Quincy, Wash. The trial consists of 'Buckeye Gala' as the scion grafted onto seven different rootstocks that were allocated to Kentucky by the NC-140 committee (Table 2). These are: one Budagovsky stock ('B.10'), two Malling stocks ('M.9 NAKBT337' and 'M.26 EMLA'), three Geneva stocks ('G.41,' 'G.814,' and 'G.969'), and a New Zealand rootstock that is being referred to as 'NZ.2' by the NC-140 cooperators. The 'NZ.2' rootstock is purported to have 'M.9' vigor, high yield efficiency, and tolerance to woolly apple aphids and fire blight (possibly immune). Yield efficiency is a measure of the amount of fruit that a tree produces relative to the amount of vegetative growth it has. 'G.814,' 'M.26,' and 'G.969' produce trees that are about 40%, 45%, and 65% of standard tree size, respectively. The other four rootstocks produce trees that are 35% of standard size.

Three trees of each rootstock were planted in each row in a randomized complete block design and trained to the tall spindle system. To eliminate the effect of more vigorous rootstocks competing with less vigorous ones, only the center trees of each of the three-tree subplots are being evaluated. Thus, the confounding effect due to different rootstock sizes adjacent to one another will be eliminated in this trial. Trunk circumference 30 cm above the graft union is measured in the fall of each season, and the trunk cross-sectional area is calculated from the trunk circumference.

Effect of Notching and 1.9% 6-benzyladenine (MaxCel Plant Growth Regulator) in the 2019 Apple Rootstock Trial

Growth regulators and notching (scoring the bark just above a bud) are often used in high-density orchards to initiate branch development along a tree trunk in areas where there are no branches, often referred to as "blind wood" (Becker, 2020; McArtney and Obermiller, 2015). This is currently a problem in the 2019 apple rootstock trial at Princeton, KY. On 23 Mar. 2020, notches were made through the cambium layer to the secondary xylem, about 3 mm above various buds along the trunk and about 4 to 6 ft above ground level in these trees (Figure 1). A mixture of white latex paint and 7500 ppm of 1.9% 6-benzyladenine (MaxCel Plant Growth Regulator, Valent U.S.A. LLC Agricultural Products) was applied to the wounds immediately after notching. The number of buds notched per tree and number of shoots at least 1 cm in length that formed were recorded, along with shoot length, on 27 Apr. 2021.

Table 1. Rootstocks in the 2010 apple rootstock trial with 'Aztec Fuji' as the scion cultivar at the University of Kentucky Research and Education Center, Princeton, KY.

Rootstock	Clone status	Breeding program	Location of program
B.9	named	Budagovsky	Michurinsk State Agrarian University Michurinsk, Tambov Region, Russia
B.10	named		
B.7-3-150	not released		
B.7-20-21	not released		
B.64-194	not released		
B.67-5-32	not released		
B.70-6-8	not released		
B.70-20-20	not released		
B.71-7-22	not released		
G.11	named	Cornell-Geneva[z]	New York State Agricultural Experiment Station
G.41 N[y]	named		
G.41 TC[x]	named		
G.202 N[y]	named		
G.202 TC[x]	named		
G.214 (formerly CG.4214)	named		
G.814 (formerly CG.4814)	named		
G.222 (formerly CG.5222)	named		
G.935 N[y]	named		
G.935 TC[x]	named		
CG.2034	not released		
CG.3001	not released		
CG.4003	not released		
CG4004	not released		
CG.4013	not released		
CG.5087	not released		
Supp.3	named	Pillnitz	Institut fur Obstforschung Dresden-Pillnitz, Germany
PiAu.9-90	not released		
PiAu.51-11	not released		
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 Research Station, Kent, England

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

[y] Stool bed produced.

[x] Tissue culture produced.

Results and Discussion

The 2010 Apple Rootstock Trial Bitter Pit Evaluation

For the 2020 season, color ratings, flesh firmness and total soluble solids of the apple samples 90 days after cold storage (measured Jan. 2021) were significantly different among rootstocks (Table 3). Fruit from 'B.9' were smaller in size and consequently were the firmest fruit (Table 3). Fruit from 'M.26 EMLA' had the highest total soluble solids. Fruit in 2020 from trees on 'M.26 EMLA' had significantly more red color than fruit on the other rootstocks. Casual observations in previous seasons suggested this result, but no ratings were recorded to confirm this observation until the 2020 season. Bitter pit was not significantly different among rootstocks at harvest or after being in cold storage for 90 days.

When data were averaged over all three years of this study (2018-2020), yield, fruit size, percentage of fruit with bitter pit both at harvest and after 90 days in cold storage, and flesh firmness were significantly different (Table 4), but total soluble solids averaged over three years were not significantly different among rootstocks. Fruit from trees on 'CG.2034' had the highest percentage of fruit with bitter pit, both at harvest and 90 days after cold storage. However, there was only one tree of this rootstock in the trial, and it was marginal in terms of tree health and vigor. Likewise, fruit size on 'B.9' tended to be smaller than fruit on other rootstocks, primarily because these trees tended to be over-cropped. These smaller fruit also tended to be significantly firmer than larger fruit, as indicated by the results of firmness testing.

Bitter pit has been shown to be related to calcium levels in the fruit, and calcium levels in fruit are influenced by rootstock (Autio et al., 1991). Apple samples were collected each of the three years of this project and sent to Cornell University for analysis as part of this cooperative project on bitter pit. Unfortunately, the authors of this report did not receive the results of the fruit nutrient analysis from Cornell in time for inclusion in this publication but will report a summary of those results at a later date.

The 2019 Apple Rootstock Trial

All trees are currently alive in this trial and have reached about 4 m or more in height at the third leaf. The average weight/fruit and the number of root suckers/tree did not vary significantly among the seven rootstocks. Trunk cross-sectional area (TCSA) at 30 cm above the graft union, number of flower clusters/tree, yield, and yield efficiency were all significantly different among the seven rootstocks (Table 5). 'G.814,' 'G.969,' 'NZ.2,' and 'M.26 EMLA' are currently the largest trees in terms of TCSA and were significantly larger than 'M.9 NAKBT337,' 'G.41,' or 'B.10.' Trees on 'G.814,' 'G.969,' and 'NZ.2' had the largest number of flower clusters. Yield was significantly higher for trees on 'NZ.2' than for the other rootstocks, except for 'G.969.' Trees on 'NZ.2' also had the highest yield efficiency in 2021 as compared to all the other rootstocks except for 'G.41.' This contrasts with 2020 results (Wolfe et al., 2020), in which 'G.41' was significantly more yield efficient than any of the other root-

Table 2. Rootstocks in the 2019 apple rootstock trial with 'Buckeye Gala' as the scion cultivar at the University of Kentucky Research and Education Center, Princeton, KY.

Rootstock	Clone status	Breeding program	Location of program
B.10	named	Budagovsky	Michurinsk State Agrarian University Michurinsk, Tambov Region, Russia
G.11[y]		Cornell-Geneva[z]	New York State Agricultural Experiment Station
G.41	named		
G.214[y]			
G.4010[y]			
G.814 (formerly CG.4814)	named		
G.935[y]			
G.969	named		
NZ.1[y]		New Zealand	New Zealand Experiment Station
NZ.2	not named		
NZ.5[y]			
M.9 NAKBT337	named	NAKB clone of M.9	NAKB, Netherlands
M.26 EMLA	named	E. Malling clone of M.26	East Malling Research Station, Kent, England

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

[y] Not in Kentucky trial.

Table 3. Results for the 2010 NC-140 apple rootstock trial bitter pit evaluation at the University of Kentucky Research and Education Center, Princeton, KY.

Rootstock[z]	Initial no. of trees	2020 TCSA[z] (in^2)	Flesh firmness (lb)[x]	Total soluble solids (°Brix)[x]	Bitter pit at 2020 harvest (%)	Bitter pit after storage, Jan. 2021 (%)[x]	Color rating[w]
M.26 EMLA	4	22.7	11.9	13.6	0.0	1.0	4.00
G.222 (G.5222)	4	16.2	12.3	12.5	0.0	0.5	2.75
CG.3001	3	15.9	12.2	13.2	0.7	1.3	2.67
G.202 N	4	15.6	12.6	11.9	0.5	1.5	2.50
G.935 N	4	15.4	12.4	11.5	0.0	0.0	2.50
M.9 Pajam2	2	14.8	12.6	11.8	0.0	0.0	2.00
G.814 (G.4814)	4	14.2	12.8	11.1	0.0	0.5	2.50
CG.4004	4	13.0	12.6	11.2	0.0	0.5	2.50
G.11	4	12.4	12.9	11.9	0.5	1.5	2.75
CG.5087	2	12.4	12.1	12.8	1.0	2.0	2.00
G.214 (G.4214)	3	12.2	12.1	12.0	0.0	0.0	2.67
M.9 NAKBT337	3	12.2	12.3	11.6	0.0	0.7	2.67
B.10	4	10.4	13.1	11.3	0.0	0.0	2.00
G.41 N	3	9.2	12.9	10.4	0.0	0.0	2.00
CG.4003	4	8.0	13.7	11.2	0.0	0.5	2.50
CG.2034	1	6.2	12.3	12.3	2.0	2.0	1.00
B.9	4	4.1	14.7	11.1	0.5	1.0	2.00
Means	NA	12.9	12.7	11.8	0.2	0.7	2.49
LSD (5%)[y]	NA	4.8	1.2	1.7	ns	ns	0.88

[z] Arranged in descending order of the trunk cross-sectional area (TCSA), calculated from the trunk circumference measured 30 cm above the graft union during the fall season of each year.

[y] Least significant difference (LSD) at $P \leq 0.05$. Differences between two means within a column that are less than the LSD value are not significantly different, and "ns" indicates variable was not significant in the analysis of variance at $P \leq 0.05$.

[x] From fruit stored for 90 days after harvest in a cooler at 40 °F.

[w] Rating scale was from 1 to 5, based on percentage of red color: 0%-20%, 21%-40%, 41%-60%, 61%-80%, and 81%-100%, respectively.

Figure 1. The painted notched bud in the foreground (1) did not break, but the painted notched bud on the opposite side of the trunk (2) did break and formed a shoot.

stocks and had the highest yield. This was the second year that these trees fruited, and this trial will need to be evaluated for at least several more years before any recommendations can be made based on results from this trial.

Table 4. Three-year (2018-2020) summary of results of the apple rootstock trial bitter pit evaluation at the University of Kentucky Research and Education Center, Princeton, KY.

Rootstock[z]	2020 TCSA[z] (in^2)	Average yield (kg/tree)	Average fruit size (g/fruit)	Average % bitter pit at harvest	Average % bitter pit after storage[x]	Flesh firmness (lb)[x]	Average soluble solids (°Brix)[x]
M.26 EMLA	22.7	79.958	176	0.37	3.56	12.6	14.9
G.222 (G.5222)	16.2	74.858	177	0.40	3.28	12.7	14.3
CG.3001	15.9	51.844	190	1.11	4.00	12.8	14.6
G.202 N	15.6	46.667	178	0.65	3.34	13.2	14.0
G.935 N	15.4	54.342	170	0.45	1.97	13.1	14.3
M.9 Pajam2	14.8	56.700	160	0.23	1.40	13.0	14.2
G.814 (G.4814)	14.2	47.275	167	1.17	3.58	13.3	14.0
CG.4004	13.0	65.667	182	0.18	2.99	13.3	14.1
G.11	12.4	47.875	177	0.92	3.39	13.6	14.1
CG.5087	12.4	62.567	174	0.63	3.45	12.7	14.8
G.214 (G.4214)	12.2	57.611	172	0.23	1.27	12.9	14.5
M.9 NAKBT337	12.2	53.944	168	0.53	1.99	12.9	14.4
B.10	10.4	40.650	162	0.53	1.81	13.2	14.3
G.41 N	9.2	37.100	164	0.86	2.29	13.0	13.5
CG.4003	8.0	31.617	153	0.68	1.89	13.4	13.8
CG.2034	6.2	29.800	183	3.27	7.20	13.3	14.3
B.9	4.1	15.692	133	1.08	1.75	14.4	13.7
Means	12.9	50.670	169	0.68	2.73	13.2	14.2
LSD (5%)[y]	4.8	28.3	22.4	2.91	2.66	0.8	ns

[z] Arranged in descending order of the trunk cross-sectional area (TCSA), calculated from the trunk circumference measured 30 cm above the graft union during the fall season of each year.

[y] Least significant difference (LSD) at $P \leq 0.05$. Differences between two means within a column that are less than the LSD value are not significantly different, and "ns" indicates variable was not significant in the analysis of variance at $P \leq 0.05$.

[x] From fruit stored for 90 days after harvest in a cooler at 40 °F.

Effect of Notching and 1.9% 6-benzyladenine (MaxCel Plant Growth Regulator) in the 2019 Apple Rootstock Trial

Of the 105 trees in the 2019 apple rootstock trial, one tree on 'M.9,' one tree on 'G.814,' and four trees on 'G.969' were not notched, because these trees did not need more branching in the area where we were notching these trees (Table 6). Only 11 of the 15 trees on 'G.969' (73%) needed notching in the area 4 to 6 ft above ground level at the time we notched these trees. However, this is not to imply that trees planted on 'G.969' in a high-density planting will need less notching than other rootstocks. Most, if not all, of the trees in this trial, including those on 'G.969,' need more branch development in the areas where new growth has occurred since this work was initially done.

There were no significant differences in the average number of notches per tree for those trees that were notched, nor were there any significant differences in average length of new shoots from the notched buds among the seven rootstocks. The percentage of the notches resulting in new shoots did vary by rootstock and was weakly correlated with trunk cross-sectional area or tree vigor, with Pearson's correlation coefficient being equal to only 0.61419. This is not a very high value and would indicate that only about 38% of the variation in shoot development is explained by tree vigor.

The growth regulator, 6-benzyladenine, is a cytokinin, a class of plant hormones that promote cell division. Along with auxin, another plant hormone, the cytokinin-to-auxin ratio appears to regulate bud growth and apical dominance by promoting secondary bud growth or branching when this ratio is relatively high. Exactly how these hormones interact to affect tree vigor and branching is not fully understood and is further complicated by rootstock interactions. More work is needed to understand these processes. Results discussed in this report are preliminary, and future data from these trials will be needed before any recommendations can be made.

Literature Cited

Autio, W., J. Barden, and G. Brown. 1991. Rootstock affects ripening, size, mineral composition, and storability of 'Starkspur Supreme Delicious' in the 1980–81 NC-140 cooperative planting. Fruit Var. J. 45(4):247–251. 21 Oct. 2021. <https://www.pubhort.org/aps/45/v45_n4_a11.htm>.

Becker, D. 2020. Promoting branching on high-density dwarf fruit trees. Univ. KY College Agr. Food Environ. Coop. Ext. Serv. Hort Fact—3011. 21 Oct. 2021. <https://www.uky.edu/hort/sites/www.uky.edu.hort/files/documents/HortFact3011-4.pdf>.

McArtney, S. and J.D. Obermiller. 2015. Effect of notching, 6-Benzyladenine, and 6-Benzyladenine plus Gibberellin A4 + A7 on budbreak and shoot development from paradormant buds on the leader of young apple trees. HortTechnology Apr. 2015 25(2):233–237. <https://journals.ashs.org/horttech/view/journals/horttech/25/2/article-p233.xml>.

Wolfe, D. 2018. Update on the 2010 apple rootstock trial at UKREC orchard, Princeton, KY. p. 4–5. In: J. Strang (ed.). KY Fruit Facts Sept.-Oct. Nwsl. 2018:4. Univ. KY College Agr. Food Environ. 21 Oct. 2021. <http://www.uky.edu/hort/sites/www.uky.edu.hort/files/documents/FFSep-Oct18.pdf>.

Wolfe, D., D. Archbold, D. Becker, J. Johnston, and G. Travis. 2018. Rootstock effects on apple tree growth and yield. p. 14–16. In: J. Snyder, R. Rudolph, C. Smigell, and J. Strang (eds.). 2018 Fruit and Veg. Crops Res. Rpt. (PR-757). Univ. KY College Agr., Food Environ. 21 Oct. 2021. <http://www2.ca.uky.edu/agcomm/pubs/PR/PR757/PR757.pdf>.

Wolfe, D., D. Archbold, D. Becker, J. Johnston, and G. Travis. 2019. Rootstock effects on apple tree growth and yield. p. 14–16. In: J. Snyder, C. Smigell, and J. Strang (eds.). 2019 Fruit and Veg. Crops Res. Rpt. (PR-762). Univ. KY College Agr., Food Environ. 21 Oct. 2021. <http://www2.ca.uky.edu/agcomm/pubs/PR/PR762/PR762.pdf>.

Wolfe, D., D. Archbold, D. Becker, and G. Travis. 2020. Rootstock effects on apple tree growth and yield. p. 4–6. In: R. Rudolph (ed.). 2020 Fruit and Veg. Crops Res. Rpt. (PR-779). Univ. KY College Agr., Food Environ. 21 Oct. 2021. <http://www2.ca.uky.edu/agcomm/pubs/PR/PR779/PR779.pdf>.

Table 5. 2021 results for the 2019 NC-140 apple rootstock trial at the University of Kentucky Research and Education Center, Princeton, KY.

Rootstock[z]	No. of data trees	TCSA[z] (in^2)	Trunk diameter (in)	Yield (lb of fruit/tree)	Fruit weight (oz/fruit)	Bloom (clusters/tree)	No. of root suckers/tree	Yield efficiency (lb/in^2 of TCSA)
G.814	5	2.64	1.83	19.7	5.5	375	1.0	7.52
G.969	5	2.41	1.74	23.1	5.4	338	0.2	9.40
NZ.2	5	2.28	1.70	31.7	6.7	344	0.4	13.72
M.26 EMLA	5	2.25	1.69	21.3	5.6	287	0.0	9.50
M.9 NAKBT337	5	1.78	1.50	14.5	5.3	254	0.6	8.30
G.41	5	1.77	1.50	18.8	5.7	260	0.2	10.93
B.10	5	1.65	1.44	14.9	5.2	272	0.0	9.14
Means		2.11	1.63	20.6	5.6	304	0.3	9.79
LSD (5%)[y]		0.45	0.18	9.4	ns	80	ns	3.51

[z] Arranged in descending order of the trunk cross-sectional area (TCSA), calculated from the trunk circumference measured 30 cm above the graft union during the fall season of each year.

[y] Least significant difference (LSD) at $P \leq 0.05$. Differences between two means within a column that are less than the LSD value are not significantly different, and "ns" indicates variable was not significant in the analysis of variance at $P \leq 0.05$.

Table 6. Results one year after notching trees in 2020 in the 2019 NC-140 'Buckeye Gala' rootstock trial at the University of Kentucky Research and Education Center, Princeton, KY.

Rootstock[z]	TCSA[y] (in^2)	No. of trees notched[x]	No. of trees in trial	Percentage of trees requiring notching	Average no. of notches/tree	Percentage of notches resulting in a new shoot	Average shoot length (cm)
G.41	1.38	15	15	100	3.20	52.1	41.7
M.9 NAKBT337	1.39	14	15	93	3.43	50.7	41.2
B.10	1.39	15	15	100	3.33	56.6	23.5
M.26	1.73	15	15	100	3.47	77.9	37.4
NZ.2	1.83	15	15	100	3.33	75.2	32.3
G.969	1.98	11	15	73	2.37	76.5	26.8
G.814	2.02	14	15	93	3.20	96.6	33.8
Mean	1.67	-		94.2	3.04	69.0	33.8
LSD (5%)[w]	0.40	-		16.5	ns	20.5	ns

[z] Arranged in descending order of the trunk cross-sectional area (TCSA).

[y] TCSA = trunk cross-sectional area, calculated from the trunk circumference measured 30 cm above the graft union during the fall season of each year.

[x] Trees that had sufficient branching were not notched.

[w] Least significant difference (LSD) $P \leq 0.05$. Differences between two means within a column that are less than the LSD value are not significantly different, and "ns" indicates variable was not significant in the analysis of variance at $P \leq 0.05$.

Insecticide Efficacy Against Ambrosia Beetles Using Apple Bolts in Kentucky

Zenaida Viloria, Raul Villanueva, and Ric Bessin, Entomology, University of Kentucky;
Win Dunwell, Horticulture, University of Kentucky

Invasive ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) occasionally cause severe damage to nursery, landscape, and fruit trees in spring. Ambrosia beetles bore the sapwood, making galleries where they farm fungi, collectively named as ambrosia fungi. These fungi are the only food source of their brood. In Kentucky, the granulate ambrosia beetle, Xylosandrus crassiusculus, is the dominant ambrosia beetle species that attacks landscape and nursery trees and shrubs (Viloria et al., 2019; Viloria et al., 2021). Physiologically stressed plants mediate the beetle attacks due to the emission of stress volatiles, mainly ethanol. It is very difficult to foresee any ambrosia beetle attack; therefore, preventative application of insecticides is the most appropriate management practice.

To test the efficacy of insecticides against ambrosia beetles, it is necessary to induce the synthesis of ethanol in healthy plants to attract and create conditions for the beetles to bore plants and establish a new colony. Ethanol synthesis has been induced in container-grown plants when the root system is totally submerged in water (Ranger et al., 2016) or when they are irrigated with ethanol at low concentrations (Ranger et al., 2018) during the ambrosia beetle seasonal flight. Ethanol injection into healthy plants also induced ambrosia beetle attacks (Reding et al., 2017). These approaches are difficult and expensive. The use of ethanol-infused bolts (tree branch segments) and bolts with drilled ethanol reservoirs are feasible alternatives to screen insecticides, evaluate damage, identify the beetle responsible for attacks, and study insecticide residual effect (Brown et al., 2020; Jones and Pine, 2018; Mayfield and Hanula, 2012; Reding and Ranger, 2018; Reding and Ranger, 2020).

Table 1. Trade and chemical names and rates of tested insecticides on apple bolts in Kentucky in the spring of 2018, 2019, and 2020.

Treatments	Rates	2018	2019	2020
β-cyfluthrin (Baythroid XL)	2.8 fl oz/10 gal	X	X	
ζ-cypermethrin (Mustang Maxx)	4.0 fl oz/10 gal	X	X	X
imidacloprid + β-cyfluthrin (Leverage 360)	2.4 fl oz/10 gal			X
λ-cyhalothrin (Warrior II with Zeon Technology)	2.56 fl oz/10 gal		X	X
Hardwood vinegar	20%, 40%	X	X	X
Croton vinegar	20%	X		
Control	-	X	X	X

Thus far, pyrethroids are the recommended insecticides to control ambrosia beetles. The main objective of this study was to assess the efficacy of three pyrethroid insecticides, a double mode of action insecticide (pyrethroid + imidacloprid), and two biopesticides against ambrosia beetles, using freshly cut apple bolts baited with ethanol.

Materials and Methods

Branches measuring 3–4 cm in diameter from healthy 'Fuji' apple trees [Malus × sylvestris (L.) Mill var. domestica (Borkh.) Mansf.] were cut into 30 cm bolts one day before beginning the experiment. A cavity was drilled at one end of each bolt to make an ethanol reservoir 0.79 cm in diameter and 4-5 cm in depth. The hollowed end was wrapped with sealing film (Parafilm, Bemis Company, Inc., Neenah, WI), and both ends were immersed for a few seconds in melted wax to reduce water loss through the cut surface.

On 9 May through 23 May 2018, a nine-bolt bundle was immersed in ß-cyfluthrin (Baythroid XL), ζ-cypermethrin (Mustang Maxx), or vinegars (20% croton or 20% and 40% wood vinegar). In a wooded lot, air-dried bolts were hung to trees and suspended about 1 m above the ground, keeping a minimum separation distance of about 3 m between bolts. After hanging the bolts, a syringe was used to inject 3–4 mL of 95% ethanol into the reservoir. Ethanol refill was completed weekly. After ethanol injection, the hole was taped to reduce ethanol evaporation. Two control treatments were included: non-pesticide-treated apple bolts with and without ethanol.

In 2019, the pesticide test was carried out in Lexington, KY, from 29 Apr. to 20 May and in Princeton, KY, from 23 Apr. to 13 May using the bolt technique described above. Apple bolts were set in wooded lots, on trees close to the edges. Chemicals tested were: ß-cyfluthrin, ζ-cypermethrin, λ-cyhalothrin (Warrior II with Zeon Technology), hardwood vinegar at 20% and 40%, and control with no pesticide. In 2020, to facilitate apple bolt deployment and sampling as well as ethanol refill, bolts were hung on a wire that was set 1 to 1.5 m from the edge of the woods and approximately 1 m above the ground. Every 1 m, a wire loop was attached to the wire to hang and keep the bolts fixed. All 2019 treatments were repeated in 2020 with the inclusion of imidacloprid + ß-cyfluthrin (Leverage 360) and the exclusion of β-cyfluthrin. Chemical concentrations and rates are listed in Table 1. All these insecticides were compared with water plus surfactant as a control treatment.

Damage caused by ambrosia beetles was recorded and included the total number of entries/bolt, percentage of superficial entries/bolt, and percentage of bolts attacked by ambrosia beetles. In 2018, nine bolts per treatment were removed and placed in a bucket (18.93 L) with a net as a lid. Eight weeks later, granulate ambrosia beetles, camphor shot borers, and black stem borers were counted. In 2019, five bolts per treatment were removed at 10 and 20 days after pesticide applications, whereas bolt removal was completed at 7, 14, and 21 days after pesticide applications in 2020. For the 2019 and 2020 experiments, bolts were removed and placed individually in 4 L containers to evaluate beetle emergence.

Results and Discussion

Ambrosia beetle attacks were successfully induced by keeping a permanent source of ethanol emission from apple bolts through a weekly refill of 95% ethanol. Bolts without ethanol had no attacks. In 2018, the experiment was completed in late spring. At that time, low numbers of ambrosia beetles were actively flying in western Kentucky (Viloria et al., 2021). However, the number of entries per bolt was below five in most of the treatments, except ζ-cypermethrin, which completely protected apple bolts from ambrosia beetle attacks (Figure 1). Control and croton vinegar showed the highest percentages of attacked bolts (> 80%). Vinegar-based biopesticides had been reported to be an effective insecticide for a variety of pests (Omulo et al., 2017). However, there is a lack of evidence of their effects on borer insects. Neither croton nor hardwood vinegar reduced ambrosia beetle attacks at solution concentrations of 20% and 40%.

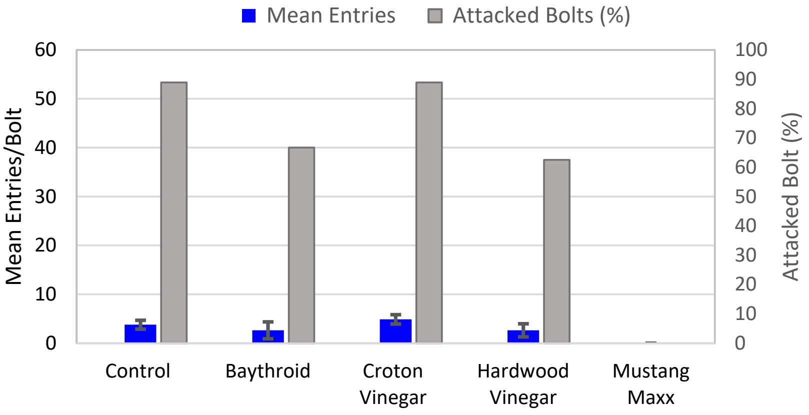


Figure 1. Efficacy of pyrethroid and botanical insecticides in preventing ambrosia beetle attacks to apple bolts in Princeton, KY, from 9 May through 23 May 2018.

The efficacy test completed in two locations in 2019 (Figure 2) showed a considerably higher number of ambrosia beetle attacks for untreated bolts and vinegar treatments at 10 days, and for all treatments at 20 days in Lexington, KY, compared with Princeton, KY. However, the trend of pesticide efficacy was similar. Pyrethroids (i.e. ζ-cypermethrin, λ-cyhalothrin, and ß-cyfluthrin) significantly reduced the number of entries per bolt. Furthermore, a high percentage of these entries were superficial (< 2 mm deep). It is likely that tested pyrethroids affect the beetles' capability to bore into the hardwood and establish a colony in treated bolts. ζ-cypermethrin significantly reduced the number of entry holes for 10 days in both locations. This insecticide was still effective in deterring ambrosia beetle attacks for 20 days, and at that time, its effect was similar to λ-cyhalothrin. β-cyfluthrin showed a similar effect as non-treated bolts. In a previous study, permethrin, a commonly used pyrethroid against ambrosia beetles, significantly reduced the number of beetle attacks in tree bolts, but did not fully prevent damage (Brown et al., 2020).

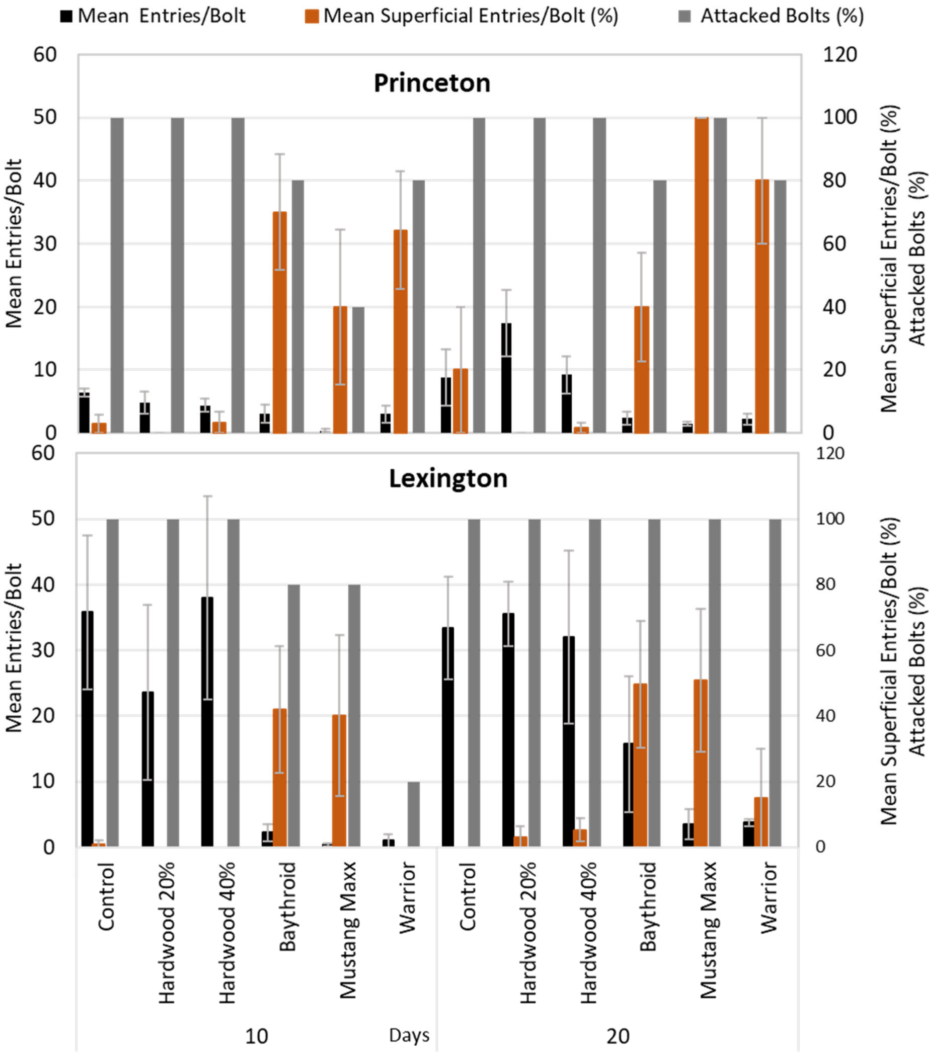


Figure 2. Efficacy of pyrethroid and botanical insecticides in preventing ambrosia beetle attacks to 'Fuji' apple bolts from 29 Apr. through 20 May 2019 in Lexington, KY, and from 23 Apr. through 13 May 2019 in Princeton, KY.

The double mode of action insecticide, imidacloprid + β-cyfluthrin, reduced the number of entries per bolt at 7 days and 21 days in the spring of 2020 (Figure 3); the systemic compound (imidacloprid) in this insecticide might have been curtailed since translocation was interrupted in cut bolts. A previous study showed that imidacloprid reduced Euwallacea sp. survival when it was soil drenched (Jones and Paine, 2018). At day 14, λ-cyhalothrin showed the lowest percentage of attacked bolts, with similar entry numbers and percentage of superficial entries to those recorded in ζ-cypermethrin. At 21 days, all apple bolts showed signs of ambrosia attacks and non-treated bolts showed the highest number of entries. Hardwood vinegar had inconsistent results when comparing 2019 and 2020. The number of entries/bolt was similar to untreated bolts in 2019 for the two sites. However, in 2020 the number of entries was significantly lower in 20% wood vinegar compared to control.

The high incidence of superficial entries suggests a potential use of these insecticides for landscape plants or fruit trees. Since the ambrosia beetles were not able to make galleries and farm ambrosia fungi, only physical damage remains, which may heal to become an undetectable scar. In the nursery crop case, minor damage caused by ambrosia beetles makes trees unmarketable, therefore it is necessary to avoid any attack.

Conclusions

In these studies, a single application of the pyrethroids, ζ-cypermethrin or λ-cyhalothrin with Zeon Technology, consistently reduced the number of ambrosia beetle entries for up to three weeks in low or high ambrosia beetle populations. However, the percentages of attacked bolts remained high (80%–100%). Preventive applications of these insecticides when ambrosia beetles emerge in spring might be a feasible practice to reduce the economic impact of this seasonal pest. The pyrethroid β-cyfluthrin did not show consistent results in Princeton, KY, and Lexington, KY, in 2019. The dual mode of action insecticide (imidacloprid + β-cyfluthrin), tested only in 2020, was as effective as ζ-cypermethrin and λ-cyhalothrin with Zeon Technology. The wood and croton vinegars did not deter ambrosia beetle attacks.

Acknowledgments

Thanks to the Kentucky Specialty Crop Block Grant Program of the Kentucky Department of Agriculture for providing funds (Award numbers PON2 035 2000000248 in2017 and PON2 035 1800000634 in 2019) for these studies. Also, we acknowledge the involvement of Christine Bradley and the summer interns Rachel Klueppel and Kendell Tobey.

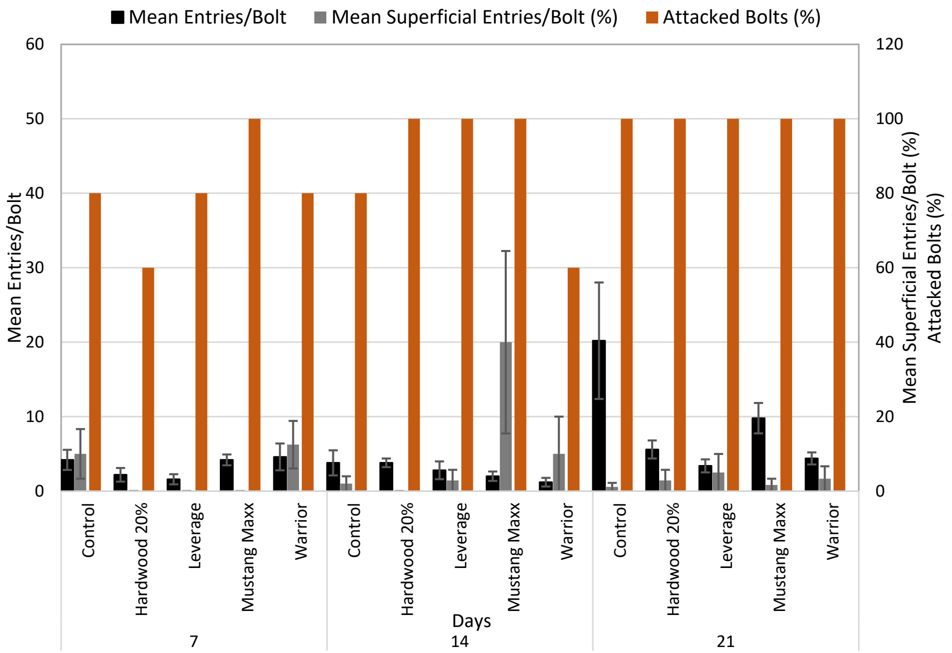


Figure 3. Ambrosia beetle attacks to 'Fuji' apple bolts after a single application of pyrethroids, double mode of action pesticide, and hardwood vinegar application from 27 Apr. through 18 May 2020 in Princeton, KY.

Literature Cited

Brown, M.S., K.M. Adesso, F. Baysal-Gurel, N.N. Youssef, and J.B. Oliver. 2020. Permethrin residual activity against ambrosia beetle (Coleoptera: Curculionidae: Scolytinae) attacks following field aging and simulated rainfall weathering. J. Econ. Entomol. 113(5):2418–2426.

Jones, M.E. and T.D. Paine. 2018. Potential pesticides for control of a recently introduced ambrosia beetle (Euwallacea sp.) in southern California. J. Pest Sci. 91:237–246.

Mayfield. A.E. and J.L. Hanula. 2012. Effect of tree species and end seal on attractiveness and utility of cut bolts to the redbay ambrosia beetle and granulate ambrosia beetle (Coleoptera: Curculionidae: Scolytinae). J. Econ. Entomol. 105(2): 461–470.

Omulo, G., S. Willett, J. Seay, N. Banadda, I. Kabenge, A. Zziwa, and N. Kiggundu. 2017. Characterization of slow pyrolysis wood vinegar and tar from banana wastes biomass as potential organic pesticides. J. Sustainable Dev. 10(3):81-92. 26 Oct. 2021. <https://doi.org/10.5539/jsd.v10n3p81>.

Ranger, C.M., P.B. Schultz, M.E. Reding, S.D. Frank, and D.E. Palmquist. 2016. Flood stress as a technique to assess preventive insecticide and fungicide treatments for protecting trees against ambrosia beetles. Insects 7(3):40. 26 Oct. 2021. <https://www.mdpi.com/2075-4450/7/3/40>.

Ranger, C.M., P.H.W. Biedermann, V. Phuntumart, G.U. Beligala, S. Ghosh, D.E. Palmquist, R. Mueller, J. Barnett, P.B. Schultz, M.E. Reding, and J.P. Benz. 2018. Symbiont selection via alcohol benefits fungus farming by ambrosia beetles. PNAS 115(17):4447-4452. 26 Oct. 2021. <https://www.pnas.org/content/pnas/115/17/4447.full.pdf>.

Reding, M.E. and C.M Ranger. 2020. Attraction of invasive ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) to ethanol-treated tree bolts. J. Econ. Entomol. 113(1): 321–329. 26 Oct. 2021. <https://doi.org/10.1093/jee/toz282>.

Reding, M.E. and C.M. Ranger. 2018. Residue age and attack pressure influence efficacy of insecticide treatments against ambrosia beetles (Coleoptera: Curculionidae). J. Econ. Entomol. 111(1): 269–276. 26 Oct. 2021 <https://doi.org/10.1093/jee/tox327>.

Reding, M.E., C.M. Ranger, J.B. Oliver, P.B. Schultz, and N.N. Youssef. 2017. Ethanol injection induces attacks by ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) on a variety of tree species. Agri. For. Entomol. 19:34–41.

Viloria, Z., R. Bessin, W. Dunwell, G. Travis, C. Ranger, and R.T. Villanueva. 2019. Evaluation of pyrethroids and new strategies to deter ambrosia beetle attacks in nurseries. SNA Res. Conf. Proc. 63:180–186.

Viloria, Z.J., R. Bessin, P. O'Neal, C. Ranger, W. Dunwell, and R.T. Villanueva. 2021. Scolytinae in nursery and fruit crops of western Kentucky and seasonal population patterns of four invasive ambrosia beetles. J. Entomol. Sci. 56(3): 374–386.

Early Fruiting Data from the Kentucky State University Advanced Selection Pawpaw Variety Trial

Sheri B. Crabtree, Kirk W. Pomper, and Jeremiah D. Lowe, Kentucky State University Land Grant Program

The North American pawpaw (*Asimina triloba*) is a tree fruit native to eastern North America, and it is being produced in small-scale commercial orchards across the United States and internationally with a growing market (Pomper and Layne, 2005). There are approximately 50 pawpaw cultivars available, but many of these varieties tend to be poor quality, low yielding, small in fruit size, and/or poor in flavor (Peterson, 2003). Recent breeding efforts for improved pawpaw cultivars have been made by breeder Neal Peterson (Peterson Pawpaws, Harpers Ferry, WV); late Terre Haute, IN, breeder

Table 1. Fruiting characteristics of two pawpaw cultivars and three advanced selections in a pawpaw variety trial established at Kentucky State University, Frankfort, KY, in 2012.

Genotype	No. of fruit per tree	Fruit weight (g)	Yield (kg)	No. of fruit per cluster
'KSU-Atwood'	99	214	21.7	3.0
'Mango'	59	161	13.5	2.4
G4-25	17	221	4.1	3.7
G9-109	67	213	14.3	2.7
G9-111	86	148	13.1	3.8
Significance[z]	NS	NS	NS	NS

[z] Least significant difference (LSD) at $P \leq 5\%$. NS indicates the variable was not significant in the analysis of variance at $P \leq 5\%$.

Table 2. Fruiting characteristics of two pawpaw cultivars and two advanced selections in a pawpaw variety trial established at Kentucky State University, Frankfort, KY, in 2017.

Genotype	No. of fruit per tree	Fruit weight (g)	Yield (kg)	No. of fruit per cluster
'KSU-Benson'	32	326	9.7	3.5
'KSU-Chappell'	38	303	11.8	3.5
Hi1-4	19	229	4.7	3.5
Hi7-1	36	217	8.2	3.0
Significance[z]	NS	NS	NS	NS

[z] Least significant difference (LSD) at $P \leq 5\%$. NS indicates the variable was not significant in the analysis of variance at $P \leq 5\%$.

Jerry Lehman; and Kentucky State University (KSU). KSU has the largest full-time pawpaw research program in the world. New high-yielding cultivars with excellent fruit quality would further assist the development of the pawpaw industry. The KSU pawpaw breeding program has released three pawpaw cultivars to date—'KSU-Atwood,' 'KSU-Benson,' and 'KSU-Chappell'—and is continuing to breed for characteristics such as excellent flavor, high yields, early ripening, firmness, and disease resistance. The objective of this study was to determine if five KSU advanced selections (G4-25, G9-109, G9-111, Hi7-1, and Hi1-4) were superior to the commercially available cultivars 'Mango,' 'KSU-Atwood,' 'KSU-Benson,' and 'KSU-Chappell' on the basis of fruit weight, number of fruit per tree, yield, and number of fruit per cluster.

Background of Included Selections

'Mango' is a popular commercially available cultivar selected in Tifton, GA, in 1970. 'KSU-Atwood' was released by KSU in 2009 and was originally a seedling selected from material collected in Maryland. 'KSU-Benson' is an open-pollinated seedling of 'Susquehanna' and was released in 2016. 'KSU-Chappell' is an open-pollinated unknown seedling from the 1998 pawpaw regional variety trial and was released in 2018. G4-25 is a seedling in the pawpaw germplasm collection originally from Ithaca, NY, that exhibited a unique pineapple-coconut flavor. G9-109 and G9-111 are crosses of PawPaw Foundation (PPF) selections 11-13 x 1-23, and Hi7-1 and Hi1-4 are open-pollinated unknown seedlings from the 1998 pawpaw regional variety trial.

Materials and Methods

Two pawpaw variety trials were established at the Kentucky State University Harold R. Benson Research and Demonstration Farm in Frankfort, KY. The first (Trial 1) was established in 2012, consisting of two commercially available cultivars ('KSU-Atwood' and 'Mango') and three KSU advanced selections (G4-25, G9-109, and G9-111). The second (Trial 2) was established in 2017, consisting of two commercially available cultivars ('KSU-Benson' and 'KSU-Chappell') and two KSU advanced selections (Hi1-4 and Hi7-1).

Trial 1 was planted in Spring 2012 with 2-year-old, potted, greenhouse-grown, chip-budded trees, including eight replicate trees per cultivar. Trial 2 was propagated via bark inlay field grafting in May 2017 with six replicate trees per cultivar. Both trials were managed conventionally with drip irrigation and fertilization with urea 34–0–0 (4 oz of nitrogen per tree), and with glyphosate, hand weeding, and mechanical weed eating for weed control as needed.

Fruit counts were performed in Aug. 2021 to determine the number of clusters per tree, number of fruit per tree, and average number of fruit per cluster. Fruit were harvested three times per week during the harvest season (10 Sept. to 1 Oct. 2021) and weighed. Data were analyzed using CoStat Statistical software (CoHort Software, Monterey, CA) and subjected to analysis of variance and least significant difference (LSD) means separation. Treatment means were separated based on a significance level of $P < 0.05$.

Results and Discussion

No differences were observed among the cultivars and advanced selections in either trial in number of fruit per cluster, number of fruit per tree, fruit weight, or yield (Tables 1 and 2).

In Trial 1, established in 2012, 'KSU-Atwood' and G9-111 both produced over 80 fruit per tree, 'Mango' and G9-109 over 50 fruit per tree, and G4-25 produced an average of 17 fruit per tree (Table 1). 'KSU-Atwood,' G4-25, and G9-109 all had fruit weights of over 200 g, with G9-111 and 'Mango' having average fruit weights over 140 g. Pawpaw varieties with fruit weighing over 120 g are considered to have a large enough fruit size for commercial sale and processing (Pomper and Layne, 2005). 'KSU-Atwood,' 'Mango,' G9-109, and G9-111 yielded over 13 kg of fruit per tree. This was higher than yields reported from the KSU/PPF regional variety trial established in 1998, which had a mean of 11.8 kg of fruit per tree across all cultivars in the 8th year after planting (Pomper et al., 2008). Number of fruit per cluster ranged from an average of 2.4 fruit per cluster ('Mango') to 3.8 fruit per cluster (G9-111). Single fruit or a low number of fruit per cluster is desirable in pawpaw due to ease of harvest and lower likelihood of fruit drop from wind and skin tearing when harvested.

In Trial 2, established in 2017, 'KSU-Benson,' 'KSU-Chappell,' and Hi7-1 all produced over 30 fruit per tree (Table 2). 'KSU-Benson' and 'KSU-Chappell' had average fruit weights of over 300 g and Hi1-4 and Hi7-1 over 200 g. These are well over the average fruit weights of older pawpaw cultivars as reported in the 1998 pawpaw regional variety trial (Pomper et al., 2008), with the highest fruit weight in 'Potomac' at 235 g, and a mean across all varieties of 139 g. Yields ranged from 4.7 kg per tree for Hi1-4 to 11.8 kg per tree for 'KSU-Chappell.' These are relatively high yields for pawpaw trees 4 years after planting, likely due to these trees being propagated via bark inlay grafting, which enables rapid growth and precocious fruit production (Crabtree et al., 2019). The mean yield across all cultivars in the 1998 variety trial 4 years after planting was 2.2 kg, with the highest yielding cultivar in that trial ('Pennsylvania Golden') producing 5.7 kg of fruit per tree. Yield and fruit number tended to be low for G4-25; this cultivar also lacks vigor (data not shown). Average number of fruit per cluster ranged from 3.0 to 3.5.

Conclusions

All KSU pawpaw advanced selections performed comparably or better to commercially available cultivars, particularly Hi7-1 and G9-109. Data on fruit weight, yield, percent seed, total soluble solids, and disease incidence will continue to be collected on these trials. Taste tests will be conducted to further evaluate these advanced selections for potential release.

Literature Cited

Crabtree, S.B, K.W. Pomper, J. Lowe, and R.N. Peterson. 2019. Precocious flowering and fruiting in bark-inlay grafted pawpaw (*Asimina triloba*) trees. HortScience 54(9):S255.

Peterson, R.N. 2003. Pawpaw variety development: A history and future prospects. HortTechnology 13:449–454.

Pomper, K.W., S.B. Crabtree, D.R. Layne, R.N Peterson, J. Masabni, and D. Wolfe. 2008. The Kentucky pawpaw regional variety trial. J. Am. Pomol. Soc. 62(2):58–69.

Pomper, K.W. and D.R. Layne. 2005. The North American pawpaw: Botany and horticulture. Hort. Rev. 31:351–384.

Plant Soil and Foliar Analyses Results from Kentucky Blueberry Plantings, 2020

Chris Smigell, John Strang, and Daniel Becker, Horticulture, University of Kentucky

More than 365 farms grow blueberries (*Vaccinium* spp.) on 343 acres across Kentucky (USDA, 2019). A number of species of blueberries are native to the United States. Most originated in areas where soil organic matter levels are high and soil pH levels are low. Kentucky's mineral soils and karst topography, covering a good portion of the state, tend to keep soil pH higher and make growing blueberries more challenging in some areas. As part of our Fruit IPM program, soil and foliar samples were collected between 15 June and 15 Aug. 2020 from 18 Kentucky commercial blueberry plantings to evaluate blueberry nutritional status across the state. It is important to collect both soil and foliar samples, as soil pH and other factors may increase or decrease nutrient uptake even when a soil sample indicates sufficient nutrient availability.

Materials and Methods

At each farm, soil samples and foliar samples were collected from a row of 10 bushes of one cultivar. Samples were collected from 12 highbush (*Vaccinium corymbosum*), five southern highbush (*Vaccinium corymbosum* interspecific hybrids), and one rabbiteye (*Vaccinium ashei*) cultivar in this evaluation. The 15 June to 15 Aug. sampling period is considered midseason for growth, beginning four to six weeks after bloom and during the time when most commercial blueberry cultivars are harvested.

One composite soil sample, consisting of eight soil probings, was collected. The probings, which were 8 in deep, were collected from just outside of the driplines of eight bushes in the row. These samples were analyzed at the University of Kentucky Soil Testing Laboratory in either Lexington, KY, or Princeton, KY. Soil samples were analyzed for pH, phosphorus (P), potassium (K) and magnesium (Mg).

Forty fully mature leaves were collected from 40 shoots throughout 10 bushes of the same cultivar within the area of the soil sample. Leaves were selected from the midportion of the current season's shoot growth and only from healthy bushes. Leaves were washed in a plastic bucket of water containing a drop of dishwashing detergent, rinsed quickly in two separate containers of water, and air-dried. All leaves from each sample were ground prior to being analyzed.

Foliar samples were sent for analysis to Waters Agricultural Laboratories, Inc. in Owensboro, KY. Their recommended highbush blueberry foliar nutrient levels were used to interpret the highbush and southern highbush samples, and their rabbiteye nutrient levels were used for the one rabbiteye sample. There was a considerable difference between the recommended foliar P values of Waters Agricultural Laboratories and those of the Agricultural Analytical Services Laboratory at Penn State University. The recommendations of Penn State University College of Agricultural Sciences (Penn State University, 2021) were used for interpreting these analyses. For all other nutrients analyzed, Waters Agricultural Laboratories nutrient levels and the Penn State levels were similar and are given in Table 3.

Results and Discussion

Soil Sample Results

More than half of the soil samples were within the optimum pH range of 4.5–5.0 (Table 1). No soil samples indicated excessive acidity (pH below 4.5). However, six samples showed a high soil pH (above 5.0), and one was excessively high. It is well established that blueberry plants grow much better at a lower soil pH because their roots have difficulty taking up iron (Fe), and this is much more available at a lower pH (Ward and Kaiser, 2013). A majority of the samples had high or excessive P levels (above 70 lb/acre), with only three showing deficient or low levels (below 35 lb/acre). Three samples were low or deficient in K (below 200 lb/acre), while three samples had low Mg (below 60 lb/acre). Five samples had excessive K (above 300 lb/acre) and four samples showed excessive Mg levels (above 120 lb/acre). Overall, the 18 soil samples suggest that Kentucky blueberry growers have been adequately managing soil fertility for their crop.

Table 1. Number of Kentucky blueberry soil samples at each pH and nutrient level ranking, 2020.

Nutrient level ranking	pH	Nutrient analyzed		
		P	K	Mg
Deficient	0	2	2	0
Low	0	1	1	3
Sufficient	11	3	10	7
High	6	2	0	4
Excessive	1	10	5	4

P = phosphorus, K = potassium, Mg = magnesium

Table 2. Number of Kentucky blueberry foliar samples at each nutrient level ranking, 2020.

Nutrient level ranking	Nutrient analyzed										
	N	P	K	Mg	Ca	S	B	Zn	Mn	Fe	Cu
Deficient	0	0	0	2	0	2	0	0	0	0	0
Low	7	1	2	9	0	11	9	12	0	2	11
Sufficient	11	17	15	7	18	5	7	6	18	16	7
High	0	0	1	0	0	0	1	0	0	0	0
Excessive	0	0	0	0	0	0	1	0	0	0	0

N = nitrogen, P = phosphorus, K = potassium, Mg = magnesium, Ca = calcium, S = sulfur, B = boron, Zn = zinc, Mn = manganese, Fe = iron, Cu = copper

Foliar Sample Results

Most samples showed sufficient levels of most nutrients, and all samples were sufficient in both calcium and manganese (Tables 2 and 3). Eleven of the samples showed sufficient nitrogen (N), and none were high or excessive, which is good. Because N readily leaches through the soil profile, it must be applied to blueberries annually. Recent research from Oregon shows that high N application levels did not increase yields (Davis and Strik, 2021). Nearly all samples in our study showed sufficient P and K. Only one site showed K to be at a high level. The same study also notes that foliar K levels above 0.55% correlate with a reduction in yield. Eleven of the foliar samples had K levels above 0.55%.

Foliar macronutrient evaluations also showed that N, Mg, and sulfur (S) were frequently low. The micronutrients boron (B), zinc and copper were also often low. It was surprising that only two samples were low in Fe, as Fe deficiency is the most common nutrient deficiency symptom seen in blueberry foliage across the state. However, many of the Fe-sufficient values bordered on low. Two samples showed deficient Mg, and two samples indicated deficient S levels. Only three samples showed high or excessive nutrient levels. One sample had high K and one had high B, while another sample showed excessive B.

Of the 18 plantings sampled, only four showed agreement between the soil and foliar analyses, indicating the same low or sufficient P status (Table 4). The soil and foliar analyses of 10 plantings indicated the same K status, and only four plantings had the same Mg status in both samples. Thus, in many cases the soil test level for P, K and Mg does not reflect what the plant is actually taking up in the foliage, substantiating the need for foliar analyses.

More than one-third of the foliar samples had low or deficient values for five or more of the 10 nutrients measured (Table 5). Only four sites showed deficient foliar levels (Mg or S). Thus, over one-third of the plantings sampled had multiple nutrients that were low, based on their foliar analyses. Plantings with multiple low foliar nutrients tend to be in central and eastern Kentucky. Only one foliar sample was sufficient for all nutrients. Analyses showed that 11 of the samples were above 0.55% K; consequently, many plantings do not need additional K applied.

Although the period between 15 June and 15 Aug. is the recommended time to conduct foliar sampling, it is also a busy time for commercial growers, and tissue sampling may not be a priority during this time. Consequently, tissue testing is rarely done. The 18 analyses indicate that Kentucky growers can improve crop performance and fruit quality by collecting a tissue sample every three to four years and adjusting their nutrition program accordingly.

Acknowledgments

Funding for this study was provided by the University of Kentucky IPM program through a grant from the USDA National Institute of Food and Agriculture Integrated Pest Management program.

Table 3. Nutrient levels for interpreting blueberry foliar analyses (provided by Penn State University).

Nutrient	Low	Sufficient	High	Excessive
Nitrogen (%)[z]	1.65	1.7	2.1	2.5
Phosphorus (%)	0.06	0.07	0.18	0.22
Potassium (%)	0.35	0.4	0.65	0.8
Calcium (%)	0.25	0.3	0.8	1.0
Magnesium (%)	0.18	0.2	0.3	0.4
Sulfur (%)	0.06	0.12	0.2	0.8
Manganese (ppm)	45	50	500	650
Iron (ppm)	65	70	300	400
Copper (ppm)	4	5	15	20
Boron (ppm)	29	30	50	65
Zinc (ppm)	9	15	30	40

[z] % = percent weight of a dry weight sample; ppm = parts per million of a dry weight sample.

Table 4. Comparing soil and foliar test results from samples collected from blueberry plantings across Kentucky, 2020.

	Equal nutrient levels in soil and foliar samples		Different levels between soil and foliar samples		
			Comparison		
Nutrient	Level	No. of farms	Soil	Foliar	No. of farms
Phosphorus	low[z]	1	low	sufficient	2
	sufficient	3	low	high	0
	high	0	sufficient	low	0
			sufficient	high	0
			high	low	0
			high	sufficient	12
Potassium	low	2	low	sufficient	1
	sufficient	8	low	high	0
	high	0	sufficient	low	2
			sufficient	high	0
			high	low	0
			high	sufficient	5
Magnesium	low	2	low	sufficient	1
	sufficient	2	low	high	0
	high	0	sufficient	low	5
			sufficient	high	0
			high	low	4
			high	sufficient	4

[z] Table has been simplified for comparison purposes; low and deficient foliar nutrient level analyses have been combined into the "low" category, and high and excessive level analyses have been combined into the "high" category.

Table 5. Nutrient status of foliar samples and the geographical distribution of sampled commercial blueberry plantings in Kentucky, 2020.

Nutrient status in samples	No. of foliar samples	Kentucky planting distribution
All nutrients sufficient or higher	1	1 west
1 nutrient low/deficient	0	
2 nutrients low/deficient	3	3 west
3 nutrients low/deficient	3	1 west, 2 central
4 nutrients low/deficient	3	2 west, 1 central
5 or more nutrients low/deficient	8	1 west, 2 east, 5 central

Literature Cited

Davis, A. and B. Strik. 2021. Long-term organic production systems in northern highbush blueberry: Placing weed mat over existing organic mulches and changing to nitrogen-only fertilizer sources increased yield. HortScience 56:897–908.

Pennsylvania State University. 2021. Interpretive nutrient levels for plant analysis, blueberries, any. Penn State College Agr. Sci. 18 Oct. 2021. <https://agsci.psu.edu/aasl/plant-analysis/plant-tissue-total-analysis/interpretive-nutrient-levels-for-plant-analysis/blueberries-any>

United States Department of Agriculture (USDA). 2019. 2017 Census of agriculture. 18 Oct. 2021. <https://www.nass.usda.gov/AgCensus/>

Ward, N. and C. Kaiser (eds.). 2013. Midwest blueberry production guide. Univ. KY College Agr. Food Environ. ID-210. 3 Nov. 2021. <http://www2.ca.uky.edu/agcomm/pubs/ID/ID210/ID210.pdf>

Performance of 'Duke' Highbush Blueberry Grown in Two Container and Three Soilless Substrate Combinations

Daniel Becker, Dwight Wolfe, Winston Dunwell, and Ginny Travis, Horticulture, University of Kentucky

The fruit of highbush blueberry (*Vaccinium corymbosum* L.) is popular with consumers for its taste and reported health benefits. Excellent sales potential exists at local markets across the state, but exacting soil requirements limit suitable production sites. Blueberries require well-drained, acidic soils with a pH between 4.5 and 5.2 and high organic matter (Strang et al., 2003). When grown in elevated pH and poorly drained soils, blueberries experience weakened growth and iron deficiency. Additionally, phytophthora root rot, a devastating fungal disease, is common and can destroy plantings. Without extensive soil amendments and the building of raised beds, the costs of which can exceed $7000/acre during site preparation, few sites in Kentucky will meet the conditions necessary for sustained productivity and long-term profitability (Ernst, 2019).

Acceptable sites are often located far from desirable markets, reducing the viability of on-farm direct-to-consumer sales. Transportation costs and risk of spoilage and contamination increase with distance. When grown on sites with good market potential but poor suitability, blueberries will fail to thrive, leading either to abandonment of cultivation or further expenses of upkeep without a commensurate increase in returns. By growing blueberries in containers, the potential exists for growers without an optimum site to successfully diversify their small farm operations. The objective of this study is to determine the adaptability of highbush blueberries to perennial container production in Kentucky.

Materials and Methods

This ongoing trial consists of 'Duke' blueberry grown singly in 25-gal containers filled with soilless substrate. The trial is located at the University of Kentucky Research and Education Center (UKREC) in Princeton, KY. The containers used were conventional blown-molded black plastic pots and flexible fabric pots called Smart Pots (High Caliper Growing System, Oklahoma City, OK). Three different substrates were evaluated: pine bark fines with a 3/8-inch average particle size, sphagnum peatmoss, and a mixture of one part pine bark with one part sphagnum peatmoss (by volume).

In Apr. 2018, 2-year-old plants were permanently transferred into 25-gal containers. Plants were originally purchased from a nursery as 1-year bareroot stock and were grown for 1 year in 7-gal containers with pine bark substrate. Containers were placed on a gravel bed spaced 4 ft apart with 13 ft between rows and arranged in a randomized complete block design. Each plot consisted of three containers of the same material, either plastic or fabric, filled with one of the three substrates, resulting in six container-substrate treatment combinations. Treatments were arranged in a row, with each row being a block of six plots and 18 plants. Rows were replicated three times for a total of 54 plants, originally, in the experiment. Further information on early plant care and experimental setup are detailed in Becker et al., 2020.

Each plant was fertilized with 267 g per container of 14.8N–8.9P–11.8K (Osmocote Plus 15–9–12, ICL Fertilizers, Dublin, OH; 12–14 months longevity at 70 °F average substrate temperature). The fertilizer was split into three 89-g applications at 6-week intervals in April (bloom), May (preharvest), and July (postharvest). Fertilizer was spread evenly over the surface of the substrate. Plants were pruned in March after winter protective covers were removed and the containers moved to the 4 × 13 ft spacing. Irrigation began in April and continued until November, when the system and supply lines were dismantled. Irrigation was programmed to run twice a day at 10:00 AM and 2:00 PM for 2-min durations (increased from 1 min in 2020) and delivered approximately one-half gallon of water per container through two 6-in staked emitters inserted into the substrate on opposite sides of each plant. Irrigation water was acidified using 93% sulfuric acid injected from a 3% stock tank solution at a 1:512 ratio (gallon-to-gallon) with pH of 5.0 as the target. In December, the containers were moved to the center of the gravel bed and arranged close together until the edges made contact. Frost covers were draped along the outside perimeter of the containers. Then, the entire canopy and containers were covered with three layers of 3 oz/yd^2 winter blankets, weighted at the edges, for freeze protection.

Data collection began in 2019 with the first year of harvest (Becker et al., 2019). Plants were not allowed to bear fruit in 2018 during establishment. Fruit were harvested weekly in June, with each plant being picked and weighed separately. A 50-berry subsample used to determine average berry weight

Table 1. Results of a continuing trial of 'Duke' highbush blueberry grown in 25-gal containers with different substrates at the University of Kentucky Research and Education Center at Princeton, KY.

		Mean yield/bush (oz)							Pour-through[v]	
Container	**Substrate**	**2019**	**2020**	**2021[z]**	**Cumulative yield, 2019–2021 (lb/bush)**	**Weight of 50 berries, 2021 (oz)[y]**	**Canopy volume, 2021 (ft^3)[x]**	**Plant mortality (% loss)[w]**	**pH**	**EC (µS/cm)**
Fabric	1 pine bark : 1 sphagnum peatmoss (by volume)	77.0	12.5	133.3 ab[u]	13.9	2.3 a	43.8 a	0	5.2	1260
Fabric	Pine bark	89.2	9.8	116.0 ab	13.4	2.3 a	53.1 a	11	4.6	1010
Fabric	Sphagnum peatmoss	73.9	13.3	130.0 ab	13.6	2.3 a	48.9 a	11	5.4	980
Plastic	1 pine bark : 1 sphagnum peatmoss (by volume)	84.7	13.2	112.6 b	13.2	2.4 a	44.5 a	11	4.8	880
Plastic	Pine bark (control)	99.5	12.2	148.8 ab	16.3	2.2 a	53.6 a	11	4.4	910
Plastic	Sphagnum peatmoss	112.1	8.8	170.4 a	18.2	2.1 a	58.9 a	11	5.2	1120

[z] Fruit was harvested over 3 weeks on 9, 17, and 25 June 2021.

[y] Weight of 50-berry subsample collected during the second harvest week.

[x] Canopy volume is calculated as the volume of a cylinder ($V = \pi * r^2 * h$). Plant height and width were assessed on 27 Sept. Height was measured by averaging the two tallest shoots from the surface of the substrate. Width was measured parallel to the row at the widest point, excluding outlying branches.

[w] Plant mortality was recorded on 27 Sept.

[v] Pour-through extraction was performed on 29 Sept. on a single randomly selected container per treatment plot. Containers were irrigated for 30 min to saturate the substrate and were allowed to drain for another 30 min. Containers were then elevated over a collection saucer and 2 L of irrigation water was poured evenly over the substrate surface. Leachate was allowed to drain into the saucer for 10 min. Leachate was tested with a calibrated portable pH/EC meter. Averages for each treatment were compiled from a single observation pooled across three replications.

[u] Means within columns followed by the same letter(s) are not significantly different (Duncan's multiple range test LSD, $P \leq 0.05$).

was collected during the second harvest. Plant height and width were measured in September to ascertain canopy volume. Plant mortality was recorded at the same time. Shortly thereafter, a pour-through extraction of the substrate was performed on a single randomly selected container per treatment. Leachate from the pour-through, along with irrigation water before and after acid injection, were tested for pH and electrical conductivity (EC). Data were statistically analyzed using SAS v.9.4 (SAS Institute, Cary, NC), subjecting it to analysis of variance (ANOVA) and means separation using Duncan's multiple range test LSD ($P \leq 0.05$).

Results and Discussion

Monthly temperatures in 2021 from January to September were near normal at the UKREC. February and May were the only notable deviations, being 8.8 °F and 3.4 °F below normal on average, respectively. The lowest temperature of 0.7 °F occurred on 16 Feb., with the highest temperature of 92.5 °F recorded on 26 Aug. (Kentucky Mesonet, 2021). Some winter injury to nonhardened shoots occurred but was expected for the conditions and amount of protection provided. Without winter blankets, injury to shoots and roots likely would have been more extensive. Overall, plant health was good after overwintering. Rainfall of 42.5 inches over the 9-month period was higher than average, with 37.3 inches considered normal, based on weather data collected from 1981-2010 (Kentucky Climate Center, 2021). June and July were exceptional, with 13.9 inches of precipitation compared to normal rainfall of 8.9 inches during these months. Precipitation was not evenly spread, with frequent 2- and 3-week dry periods occurring, punctuated by considerable rainfall events. Manual irrigation, in addition to water supplied automatically, was frequently necessary to avoid excessive substrate drying and plant stress.

Fruit was harvested over 3 weeks on 9, 17, and 25 June 2021 (Table 1). Bushes in plastic containers with sphagnum peatmoss produced the most fruit, but they were only significantly different from those in plastic containers with 1:1 pine bark to sphagnum peatmoss (by volume) as a substrate. Cumulative yields collected over 3 years show a similar treatment pattern. Berry weights were not significantly different. However, fruit size of bushes grown in the plastic-sphagnum peatmoss combination was slightly smaller than those collected from other treatments. Heavy crop loads will diminish berry size as it is necessary for plants to partition limited resources from mature leaves and storage organs in the roots and stems among more numerous carbohydrate (energy) sinks in the developing fruit. This is despite the influence of canopy size, though it is interesting to note the association between total volume and yield in this study. Compared to 2021, berry weight in 2020 was roughly 10% to 20% larger when crop load was reduced by pruning and frost loss (Becker et al., 2020). Bushes were minimally pruned on 4 Mar. as evidenced by the much larger canopy volumes measured in Sept. 2021 as compared to 2020. All treatments except the fabric and 1:1 pine bark to sphagnum peatmoss combination have had a single bush die, an 11% mortality rate.

The one-half gallon of water/day supplied to each container in this study was a compromise between the differing moisture-retention properties of the substrates, container design, and the expected variability of rainfall. Pine bark has a lower water-holding capacity, which may have negatively influenced growth (Kingston et al., 2017). Peat drains more slowly and has more easily available water for plant roots, at least initially. Water stress is more of a risk for bushes grown in fabric containers, compared to those in plastic. Fabric containers have a larger surface area of substrate exposed to air and will dry more rapidly. The number and duration of irrigation cycles was chosen to limit the possibility of overwatering during weeks with frequent rainfall. Irrigation was probably adequate during weeks with normal precipitation but inadequate during weeks when insufficient supplemental rainfall occurred. Additional irrigation was provided as needed during these periods by manually turning on a solenoid at the bed to fully wet the substrates. This might have been enough for some treatments but not for others.

Substrate drainage can also affect nutrient retention. Substrates with low water-holding capacity (i.e., those that drain quickly) may increase leaching of nutrients and have lower EC values. In contrast, the enhanced surface exposure of fabric containers may cause higher EC values when combined with nutrient- and water-retentive substrates (i.e., those that drain slowly). The average EC of the pour-through leachate tested on 29 Sept. 2021 was between 880–1260 µS/cm, including 270 µS/cm from the municipal water source, and is within the recommended range for highbush blueberry. The suggested EC levels for blueberry plants grown in pine bark substrate are 500–750 µS/cm (Krewer and Ruter, 2012), with total concentrations above 1500 µS/cm likely to negatively affect growth (Machado et al, 2014). The base pH of the irrigation water was 7.3 before and 5.5 after acid injection. The average pH values of the leachate were between 4.4 and 5.4, which is near the acceptable range for highbush blueberry grown in soil (Strang et al., 2003).

Annual and cumulative yield response is beginning to indicate that bushes are being affected by container and substrate combinations. Treatment differences, though not significant for berry weight, canopy volume, and plant mortality, are increasing. Several years are often required for perennial plants to produce a meaningful response in an experiment. Results are expected to adjust over time. Future outcomes may be radically different than those currently reported.

Acknowledgments

Funding for this project was provided by a grant from the Kentucky Horticulture Council through the Agriculture Development Fund. The authors wish to express their appreciation to Dr. Winston Dunwell for help with programming the automatic irrigation system controller and for assisting with harvest.

Literature Cited

Becker, D., D. Wolfe, W. Dunwell, and G. Travis. 2019. Effect of container and substrate composition on the productivity and growth of ‘Duke’ highbush blueberry. p. 10–11. In: J. Snyder, C. Smigell, and J. Strang (eds.). 2019 Fruit Veg. Crops Res. Rpt. PR-762. Univ. KY College Agr. Food Environ. 19 Oct. 2021. <http://www2.ca.uky.edu/agcomm/pubs/PR/PR762/PR762.pdf>.

Becker, D., D. Wolfe, W. Dunwell, and G. Travis. 2020. Performance of ‘Duke’ highbush blueberry grown in two container and three soilless substrate combinations. p. 7–9. In: R. Rudolph (ed.). 2020 Fruit Veg. Crops Res. Rpt. PR-779. Univ. KY College Agr. Food Environ. 19 Oct. 2021. <http://www2.ca.uky.edu/agcomm/pubs/PR/PR779/PR779.pdf>.

Ernst, M. 2019. 2019 Blueberry cost and return estimates. Univ. KY College Agr. Food Environ. Coop. Ext. Serv. Ctr. Crop Diversification Budget. CCD-BG-2. 19 Oct. 2021. <https://www.uky.edu/ccd/sites/www.uky.edu.ccd/files/2019blueberry_cost&return.pdf>.

Kentucky Climate Center. 2021. Historical perspective. Normals. Princeton 1 SE Sta. KY Climate Ctr. Western KY Univ. 20 Oct. 2021. <http://kyclimate.org/normals/USC00156580.html>.

Kentucky Mesonet. 2021. Monthly climatological summary. Caldwell County, Princeton, KY. KY Climate Ctr. Western KY Univ. 20 Oct. 2021. <http://www.kymesonet.org/monthly_summaries.html?county=PRNC>.

Krewer, G. and J. Ruter. 2012. Fertilizing highbush blueberries in pine bark beds. Univ. GA Coop. Ext. College Agr. Environ. Sci. College Family Consumer Sci. Bul. 1291. 21 Oct. 2021. <https://secure.caes.uga.edu/extension/publications/files/pdf/B%201291_3.PDF>.

Machado, R.M.A., D.R. Bryla, and O. Vargas. 2014. Effects of salinity induced by ammonium sulfate fertilizer on root and shoot growth of highbush blueberry. Acta Hort. 1017:407–414.

Kingston, P.H., C.F. Scagel, D.R. Bryla, and B. Strik. 2017. Suitability of sphagnum moss, coir, and douglas fir bark as soilless substrates for container production of highbush blueberry. HortScience 52(12):1692–1699.

Strang, J., R.T. Jones, J. Masabni, D. Wolfe, J. Hartman, and R. Bessin. 2003. Growing highbush blueberries in Kentucky. Univ. KY College Agr. Food Environ. Coop. Ext. Serv. HO-60. 19 Oct. 2021. <http://www2.ca.uky.edu/agcomm/pubs/ho/ho60/HO60.PDF>.

Determining the Cause of Grapevine Trunk Disease and Dieback

Henry Smith, Edward Dixon, and Nicole Gauthier, Plant Pathology, University of Kentucky; Sean Lynch, Horticulture, University of Kentucky

There are over 550 acres of table and wine grapes (*Vitis* spp.) in Kentucky, ranging from small to large operations (United States Department of Agriculture, 2017). Grapevines and fruit are susceptible to a range of diseases, particularly during wet or humid conditions (Wilcox et al., 2015). Some of the most severe losses are caused by grapevine trunk diseases (GTDs), which cause plant dieback and eventual death. The most common GTDs include Botryosphaeria dieback and Eutypa dieback, which are caused by ascomycetous fungi *Botryosphaeriaceae* family members and *Eutypa lata,* respectively (Gramaje et al., 2018). Petri disease and Esca are notable vascular diseases for grapevines in the southern and western United States that are caused by *Phaeomoniella* sp., *Phaeoacremonium* spp., and other fungi.

A wine grape cultivar trial was planted in 2006 at the University of Kentucky Horticulture Research Farm in Lexington, KY. This trial included 15 different grape cultivars planted in a randomized design and included 12 vines per cultivar (four replications of three-vine panels). Vines were sprayed to control major fungal and insect pathogens, and yield per vine was adjusted annually to achieve a Ravaz index between 8 and 10. Vines generally expressed moderate to high vigor for the first 5 to 10 years. However, some cultivars began to express a slow reduction in vine size beginning in 2014. Symptoms such as yellowing and stunting occurred, with some vines exhibiting cordon dieback and death. The goal of this study was to identify the presence or absence of GTDs in the vines expressing reduced vine size.

Materials and Methods

Trunks from vines exhibiting declining vine size were surveyed for GTDs upon plant removal in 2019. Samples from eight different grape cultivars ('Norton,' 'Traminette,' 'Vidal Blanc,' 'St. Vincent,' 'Chardonel,' 'Noiret,' 'Villard,' and 'Chambourcin') were collected for analysis of a total of 42 samples. Symptoms were documented for each sample, including patterns of necrosis of cambium and vascular tissue.

Two different methods were used to isolate potential pathogens. The first method began with cutting cross sections from trunks at a thickness of approximately 0.25 to 0.5 in. The sections were placed in a moist chamber (98% RH) for 72 h to induce fungal growth (Figure 1). Sporulating fungi were isolated and immediately examined using a dissection and light scopes (Leica Microsystems, Morrisville, NC) and confirmed morphologically by characteristic reproductive structures such as pycnidia and chlamydospores.

The second method included surface sterilization of cross sections using 70% ethanol for 1 min. Thin shavings from each canker margin were taken using a scalpel. The shavings were then plated onto acidified quarter-strength potato dextrose agar plates (Figure 2) and stored in ambient light at room temperature (22 °C to 24 °C). Resulting fungal growth was examined using a light microscope. Most fungi were identified based on colony morphology and reproductive structures at ×200 magnification.

Two resulting fungi could not be accurately identified by morphology alone. Molecular analysis was used for confirmation. Genomic DNA was extracted using a Zymo Research Fungal/Bacterial Mini Prep Kit (Zymo Research, Irvine, CA), followed by amplification of the diagnostic locus internal transcribed spacer (ITS) using the primers ITS1 and ITS4 (White, 1990). The resulting PCR product was submitted for Sanger sequencing (Eurofins Genomics LLC, Louisville, KY). Resulting sequences were edited using GeneStudio software and consensus sequences were compared to GenBank database (ncbi.nlm.nih.gov/genbank/) using the BLASTn function.

Results and Discussion

Necrosis and discoloration were limited to exposed tissues, such as in cracks and openings. Mild vascular tissue damage was also observed (Figure 3).

Seven different fungi were identified from samples in various frequencies: *Aspergillus* sp., *Magnibotryascoma* sp., *Mucor* sp., *Penicillium* sp., *Pestalotia* sp., *Phaeoacremonium* sp., and *Trichoderma* sp. (Figure 4).

Most of the fungal genera isolated were nonpathogenic to *Vitis* spp. and not capable of causing cankers or necrosis. *Botryosphaeria* spp., *Eutypa* spp., and *Phomopsis* spp., commonly reported causes of GTDs, were not isolated in this study. The only pathogenic fungus isolated from samples was *Phaeoacremonium minimum*, one of the fungi associated with Petri disease (Gramaje et al., 2015); *P. minimum* was confirmed in five of the 42 samples: three from 'Villard' and two from 'Chambourcin.'

Symptoms of Petri disease, including dieback, stunting, shorted internodes, and chlorotic foliage, may resemble abiotic disorders, including winter damage and water stress (Gramaje et al., 2018). However, Petri disease symptoms also include vascular streaking as a result of gummosis within vessels, clogging xylem flow, and result in low vigor and reduced growth (Appel and Brown, 2017). The cross sections of samples with *P. minimum* from this study (Figure 3) did not possess enough xylem hinderance to constitute Petri disease as the primary cause of dieback.

In both 2014 and 2015, abnormally cold midwinter temperatures occurred (weather.uky.edu). The cultivars sampled in this survey are reported to have moderate winter hardiness, with tolerable temperatures ranging from -5 °F to -25 °F. In Feb. 2015, temperatures at the research farm reached a low of -13.1 °F. Multiple samples, including those from which *P. minimum* was isolated, included cracks (Figure 3), likely the product of a hard freeze. Cracks and wounds allow for fungi to colonize interior plant tissue. No patterns emerged regarding symptom characters and fungal colonizer. Therefore, the

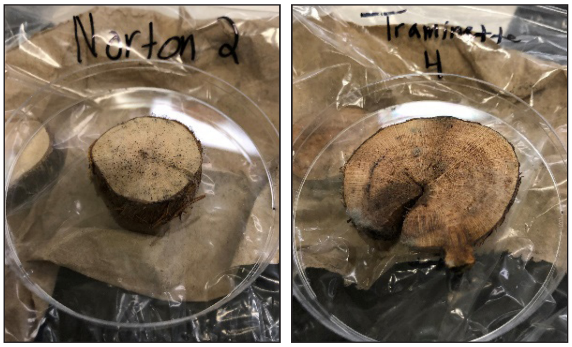


Figure 1. Images of cross sections after 72 h in humidity chamber. *Photos by Henry Smith.*

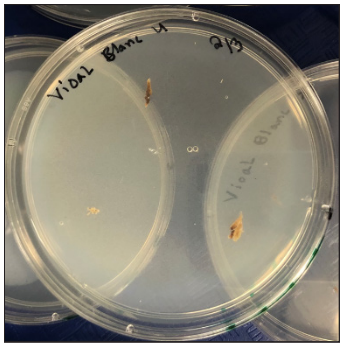


Figure 2. Surface sterilized shavings on acidified quarter-strength PDA plates. *Photo by Henry Smith.*

Figure 3. A cross section of a 'Villard' grapevine that P. minimum was isolated from. The vine shows typical discoloration of exposed pith tissue. *Photo by Henry Smith.*

primary cause of dieback in this vineyard is inferred to be winter damage.

This study confirms the presence of *Phaeoacremonium minimum* in this vineyard, a first report of the fungus in Kentucky. Growers should take extra caution when introducing new stock into vineyards to prevent a Petri disease outbreak in the future. The best defense against diseases such as Petri disease is the implementation of good cultural practices, such as using clean, healthy propagation materials, including scion and rootstock; proper planting; and avoidance of overcropping when vines are young (Appel and Brown, 2017). In addition, effective ways to prevent the spread of GTDs include focusing on overall vineyard sanitation and timing pruning strategically, using sound techniques.

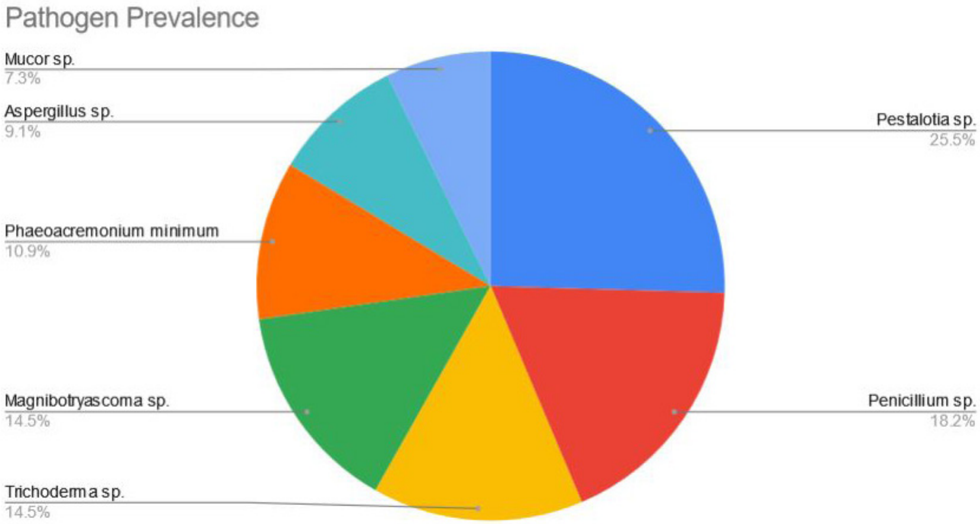


Figure 4. Summary of pathogen prevalence on grapevines grown in Lexington, KY.

Literature Cited

Appel, D. and A. Brown. 2017. Grapevine Trunk Disease. TX A&M Agrilife Ext. Serv. Aug. 2021 < https://agrilifeextension.tamu.edu/library/landscaping/grapevine-trunk-disease/>

Gramaje, D., J. Úrbez-Torres, and M. Sosnowski. 2018. Managing Grapevine Trunk Diseases with Respect to Etiology and Epidemiology: Current Strategies and Future Prospects. Plant Dis. 102(1):12–39.

Gramaje, D., L. Mostert, J. Groenewald, and P. Crous. 2015. Phaeoacremonium: from Esca Disease to Phaeohyphomycosis. J. Fungal Biol. 119(9): 759–783.

United States Department of Agriculture. 2017. Census Agr. Aug. 2021 <https://www.nass.usda.gov/Quick_Stats/CDQT/chapter/1/table/37/state/KY/year/2017>

White, T.J. 1990. Amplification and Direct Sequencing of Fungal Ribosomal RNA Genes for Phylogenetics. 315-322. In: PCR Protocols: A Guide to Methods and Application. Academic Press, New York, NY.

Wilcox, W.F., W.D. Gubler, and J.K Uyemoto. 2015. Compendium of Grape Diseases, Disorders, and Pests. 2nd ed. Amer. Phytopathological Soc. Press, St. Paul, MN.

Performance of Three Primocane-Fruiting Blackberry Cultivars Grown Organically at Kentucky State University

Jeremiah D. Lowe, Sheri B. Crabtree, and Kirk W. Pomper, College of Agriculture, Community, and the Sciences, Kentucky State University; John R. Clark, Horticulture, University of Arkansas; John G. Strang, Horticulture, University of Kentucky

In Kentucky, more than 776 farms grow berry crops, including 487 farms that grow blackberries (*Rubus* L. subgenus *Rubus* Watson), which are valued at over $2,620,000 annually (USDA, 2019). 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 blackberry, also known as fall-fruiting and everbearing blackberry, have the potential to produce two crops per year: a normal summer crop on the floricane and a later crop on the primocanes of the current season. Primocanes flower and fruit from midsummer 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 or early spring to obtain a primocane crop only; this also provides control for anthracnose, cane blight, and red-necked cane borer without pesticides (Clark, 2008). Relying only on a primocane crop also avoids potential winter injury of floricanes. However, late-ripening blackberries are more prone to spotted wing Drosophila infestations, so growers who are marketing the berries will need to maintain a pest control program.

The first commercially available primocane-fruiting blackberry cultivars, 'Prime-Jim' and 'Prime-Jan,' were released by the University of Arkansas in 2004 (Clark et al., 2005). 'Black Magic' 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 (Clark and Perkins-Veazie, 2011). 'Prime-Ark Freedom' was the first thornless primocane-fruiting blackberry and produces large fruit, but displays inferior shipping traits compared to 'Prime-Ark 45' (Clark, 2014). '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 (Clark and Salgado, 2016). In the fall of 2017, advanced selection APF-205T was released as 'Stark Black Gem' and in 2021 APF-268 was released as 'Prime-Ark Horizon.' 'Prime-Ark Horizon' 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 'Prime-Ark Horizon' in terms of yield and fruit quality under Kentucky growing conditions. Here we report results from the variety trial in its fourth and fifth years of fruit production.

Materials and Methods

In May 2016, a primocane-bearing blackberry variety trial was planted at the Kentucky State University Research and Demonstration Farm on certified organic land. The planting contained the selections 'Prime-Ark Traveler,' 'Stark Black Gem,' and 'Prime-Ark Horizon,' 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 'Prime-Ark Horizon' (total of 20 plants of each selection) in 10-ft plots with an in-row plant spacing of 2 ft. This trial was managed using organic practices following the National Organic Program standards. A combination of cultivation, hand weeding, and straw mulch was used for weed management. Drip irrigation was used as needed. Plots were fertilized with 10N–2P–8K fertilizer (NatureSafe; Griffin Industries LLC, Cold Spring, KY) at 100 lb/acre of nitrogen (N). Beginning in early June, primocanes were tipped on all selections at 1 m to promote lateral branching and flowering. Ripe fruit were harvested twice per week from late June through mid-October in 2020 and 2021. 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 early July until mid-Oct. 2020 and late June until mid-Oct. 2021. The results presented in this report are for floricane and primocane crops combined for 2020 and 2021. Growing conditions in 2020 and 2021 were warm; daily high temperatures were above 85 °F for 55 out of 122 days from June through Sept. 2020 and 50 out of 122 days in 2021. The average high for July was 88 °F in 2020 and 84 °F in 2021 (Kentucky Mesonet, 2021). The high temperatures likely reduced fruit set, fruit weight, and quality on primocanes, especially in 2020.

There was no significant difference in average fruit weight in 2020, with all selections having fruit over 3.5 g (Table 1). In 2021, 'Stark Black Gem' had significantly larger fruit than 'Prime-Ark Horizon' and 'Prime-Ark Traveler' (4.63 g, 4.25 g, and 3.91 g, respectively). There was no significant difference in yield in 2020 or 2021, and overall yields in 2021 were much higher than they were in 2020, likely due to the milder summer temperatures in 2021.

Table 1. Average yields and berry weights for 'Prime-Ark Traveler', 'Stark Black Gem', and 'Prime-Ark Horizon' at the Kentucky State University Harold R. Benson Research and Demonstration Farm, Frankfort, KY, in 2020-2021.

	2020		2021	
Selection	Avg. fruit weight (g)	Avg. yield (lb/acre)	Avg. fruit weight (g)	Avg. yield (lb/acre)
Stark Black Gem	4.61^z a	1235 a	4.63 a	2536 a
Prime-Ark Traveler	3.55 a	967 a	3.91 c	2775 a
Prime-Ark Horizon	4.49 a	2187 a	4.25 b	2569 a

^{z} Numbers in a column followed by the same letter are not significantly different (least significant difference P < 0.05).

The University of Arkansas Blackberry Breeding Program recommends that commercial producers plant 'Prime-Ark Traveler' due to its superior shipping and storage qualities. 'Prime-Ark Horizon' is recommended to growers as the less thorny alternative to 'Prime-Ark 45.' 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 suggest 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.

Literature Cited

Clark, J.R., J. N. Moore, J. Lopez-Medina, C. Finn, and P. Perkins-Veazie. 2005. 'Prime-Jan' ('APF-8') and 'Prime-Jim' ('APF-12') primocane-fruiting blackberries. HortScience 40:852–855.

Clark, J.R. 2008. Primocane-fruiting blackberry breeding. HortScience 43(6):1637–1639.

Clark, J.R. and P. Perkins-Veazie. 2011. 'APF-45' primocane-fruiting blackberry. HortScience 46:670–673.

Clark, J.R. 2014. 'Prime-Ark® Freedom' primocane-fruiting thornless blackberry. HortScience 49(8): 1097–1101.

Clark, J.R., K. Demchak, C.E. Finn, J.D. Lowe, K.W. Pomper, and S.B. Crabtree. 2014. 'Black Magic™' (APF-77) primocane-fruiting blackberry. J. Amer. Pomol. Soc. 68:163–170.

Clark, J.R. and A. Salgado. 2016. 'Prime-Ark® Traveler' primocane-fruiting thornless blackberry for the commercial shipping market. HortScience 51(10): 1287–1293.

Kentucky Mesonet. 2021. Franklin County Monthly Climatological Summary. 20 Oct. 2021. http://www.kymesonet.org/monthly_summaries.html?county=LSML.

Stanton, M.A., J.C. Scheerens, R.C. Funt, and J.R. Clark. 2007. Floral competence of primocane-fruiting blackberries Prime-Jan and Prime-Jim grown at three temperature regimens. HortScience 42: 508–513.

United States Department of Agriculture. 2019. 2017 Census of agriculture. 20 Oct. 2021. https://www.nass.usda.gov/AgCensus/.

Impact of Mixing Biochar with Animal Manures on the Yield of Three Varieties of Turnips

George F. Antonious, Environmental Studies, College of Agriculture, Community, and the Sciences, Kentucky State University;
Mohammad H. Dawood, Horticulture and Landscape, University of Kufa, El-Najaf, Iraq;
Eric T. Turley and Rance B. Paxton, Environmental Studies, College of Agriculture, Community, and the Sciences, Kentucky State University

Soil biology and fertility are dependent on soil microorganisms that promote crop production through soil enzymatic activity, organic matter decay, and nutrient availability to growing plants.

Animal manures are contributors of soil fertility due to their microbial content. When biomass, such as wood, manure, or leaves, is burned in a closed container with little or no air to produce biochar, this process is known as pyrolysis. Application of biochar, produced by incinerating wood, as a soil amendment was proposed to enhance plant nutrient availability, soil electrical conductivity (EC), soil organic matter (Haipeng et al., 2017), retention of soil water content, soil microbial population, and crop yield (Ferreira et al., 2017; Renner, 2007). Studies have indicated that soil biotic properties are associated with the influence of biochar on soil carbon maintenance, microbial populations, and enzymatic actions (Lehmann et al., 2011).

The biochar production process is unique because it takes more carbon (C) out of the atmosphere than it releases. Small amounts of C are released back into the air during the pyrolysis process and the rest is sequestered or locked up for long periods in the form of biochar. In addition, biochar helps to provide a suitable habitat for soil microbes to allow them to decompose soil organic matter (Shen et al., 2016). Research results indicated that the conversion of biomass into biochar could not only result in renewable energy (synthetic gas and bio-oil) but also decrease the content of carbon dioxide in the atmosphere (Fraser, 2010). The objectives of the current investigation were to 1) assess the impact of soil amendments [sewage sludge (SS), horse manure (HM), chicken manure (CM), vermicompost (Vermi), commercial organic fertilizer (Org), commercial inorganic fertilizer (Inorg), and no-mulch native soil (NM)] on turnip (*Brassica rapa*) root, shoot, and plant weight; and 2) assess the impact of biochar added to SS, HM, CM, Vermi, Org, Inorg, and NM on the root, shoot, and plant weight of three varieties of turnip ['Purple Top White Globe' (PTWG), 'Scarlet Queen Red' (SQR), and 'Tokyo Cross' (TC)] grown under field conditions.

Figure 1. Amendments used for growing turnip under field conditions, including A) sewage sludge, B) chicken manure, C) organic fertilizer (Nature Safe, 10N-2P-8K), D) inorganic fertilizer (19N-19P-19K), E) horse manure, and F) vermicompost.

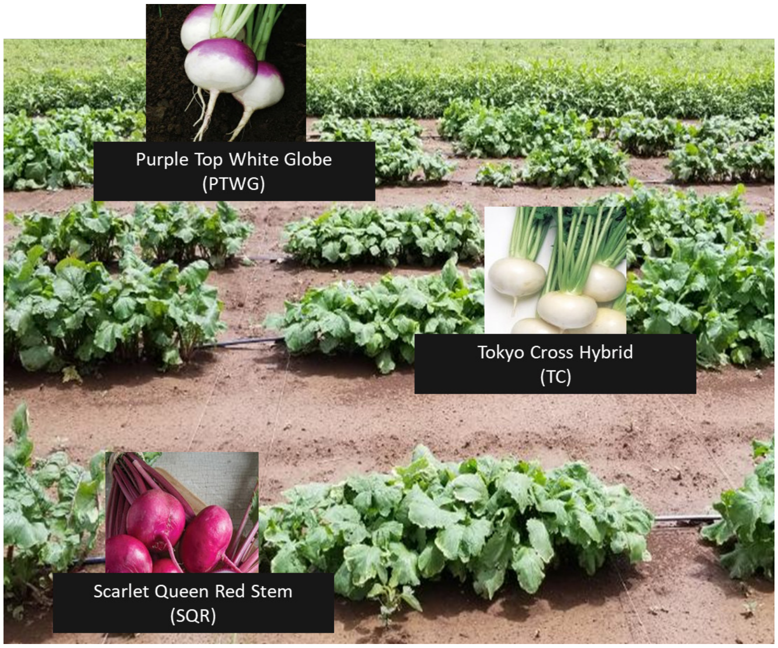


Figure 2. Three varieties of turnip (*Brassica rapa*) grown at the University of Kentucky Horticulture Research Farm (Lexington, KY).

Materials and Methods

The experimental study at the University of Kentucky Horticultural Research Farm (Fayette County, KY) included a randomized complete block design (RCBD). Sixty-three 4 × 3 ft field plots (three turnip varieties × seven treatments × three replicates) were used for biochar treatments and 63 plots (4 × 3 ft) were used for no-biochar treatments for comparison purposes. Three varieties of turnip (PTWG, SQR, and TC) were investigated. The seven soil treatments (Figure 1) included SS, HM, CM, Vermi (worm castings), Inorg (19N–19P–19K), Org (Nature Safe 10N–2P–8K), and NM used as control treatment. Biochar obtained from Wakefield Agricultural Carbon (Columbia, MO) was added to soil amendments at the rate of 10% (w/w). The native soil in the experimental plots was a

Bluegrass-Maury Silt Loam (2.2% organic matter, pH 6.2) and the soil had an average of 56% silt, 38% clay, and 6% sand.

Soil amendments used in this investigation were mixed with native soil prior to planting on 14 May 2019 at 5% nitrogen (N) on a dry weight basis to eliminate variations among soil treatments due to their variability in N content. SS was purchased from the Metropolitan Sewer District (Louisville, KY) and CM was obtained from the Department of Animal and Food Sciences, University of Kentucky (Lexington, KY). HM was obtained from the Kentucky Horse Park (Lexington, KY) and Vermi was obtained from Worm Power (Montpelier, VT). Each amendment was added to native soil and rototilled to a depth of 15 cm (~ 0.5 ft) topsoil. Turnip varieties were hand-seeded on 15 May in a freshly tilled soil at 18-in in-row spacing and drip irrigated as needed. Weeding and other agricultural operations were carried out during the growing season regularly as needed. The plants were sprayed with a mixture of two pyrethroid insecticides, esfenvalerate (Asana XL) and β-cyfluthrin (Baythroid XL), three times during the growing season. The three turnip varieties (Figure 2) were removed from the soil at maturity on 26 July (71 days old), cleaned with water, and weighed. Their shoots and roots were separated using a sharp knife, and their weights were recorded.

Data containing root, shoot, and plant weight of each variety grown under the different soil treatments were statistically analyzed using analysis of variance (ANOVA), and the means were compared using Duncan's multiple range test (SAS Institute, 2016).

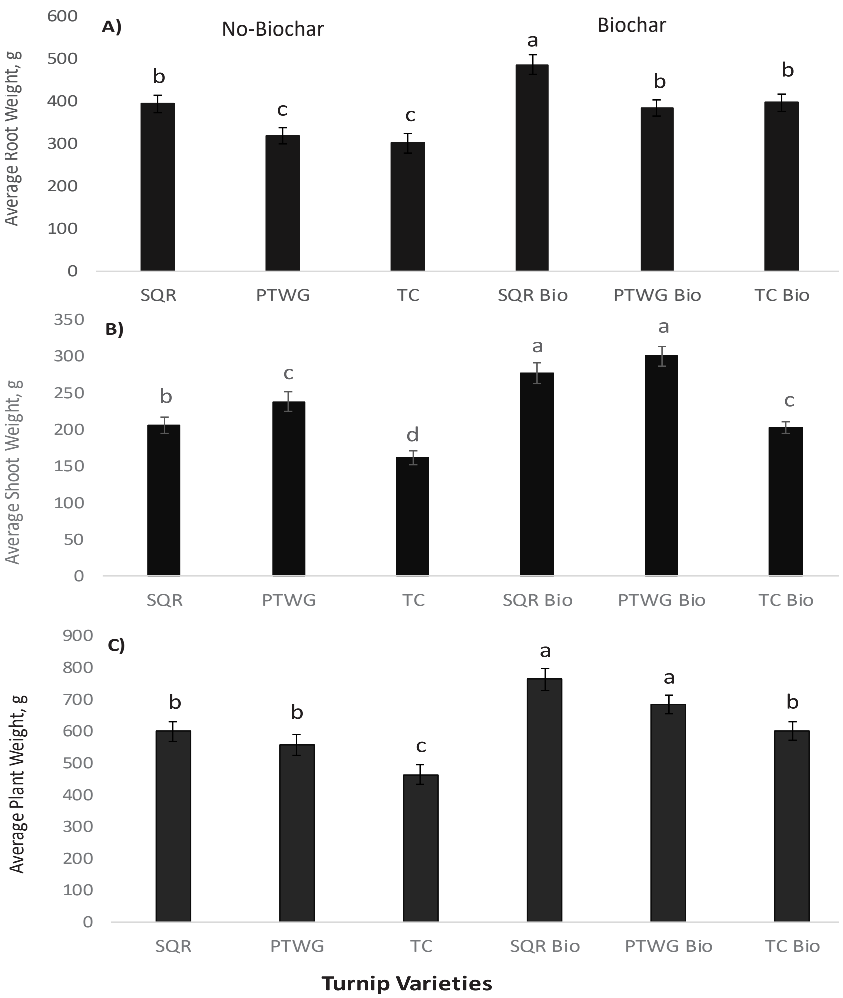


Figure 3. Impact of soil treated with biochar on the A) root, B) shoot, and C) plant weight of three varieties of turnip [Scarlet Queen Red (SQR), Purple Top White Globe (PTWG), and Tokyo Cross (TC)], and those same varieties grown in soil without biochar, regardless of soil amendments. Statistical comparisons were carried out among varieties for each plant part or plant weight. Bars accompanied by a different letter indicate significant differences ($P < 0.05$) using Duncan's multiple range test.

Results and Discussion

Results revealed that varieties grown in soil treated with biochar had significantly greater root, shoot, and plant weight ($P < 0.05$) compared to the same varieties grown in soil not treated with biochar (Figure 3). This increase in crop yield due to the addition of biochar might support the observation that biochar helps in providing suitable habitat for soil microbes to decompose soil organic matter and release the nutrients needed for growing plants.

Regardless of the soil amendments used in this investigation, the root yield of variety SQR was significantly increased compared to the PTWG and TC varieties (Figure 4), whereas variety PTWG had the greatest shoot weight compared to SQR and TC. As a result, turnip varieties can be arranged based on their yield in a descending order as follows: SQR > PTWG > TC.

Overall turnip shoot, root, and total plant weight obtained from CM-amended soil not amended with biochar (295.9, 524.4, and 820.3 g, respectively) was significantly greater (P

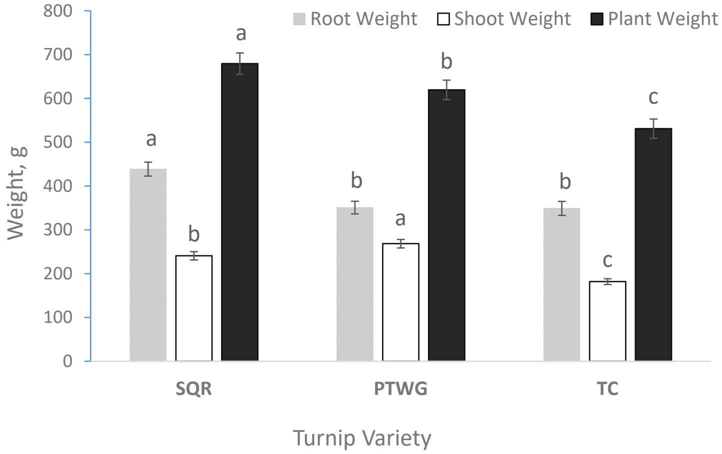


Figure 4. Variability of three varieties of turnip ['Scarlet Queen Red' (SQR), 'Purple Top White Globe' (PTWG), and 'Tokyo Cross' (TC)] in root, shoot, and plant weights, regardless of soil treatments. Statistical comparisons were carried out among varieties for each plant part or plant weight. Bars accompanied by a different letter indicate significant differences ($P < 0.05$) using Duncan's multiple range test.

< 0.05) compared to average shoot, root and plant weight obtained from NM treatment (147.3, 242.5, and 389.8 g, respectively), regardless of turnip variety (Figures 5 and 6). Biochar added to SS, Org, Vermi, and HM significantly increased the average plant weight, from 522.3, 482.5, 476.5, and 450.2 g to 737.5, 701.9, 673.3, and 640.8 g, respectively (Figure 6). We recommend the use of variety SQR for growing turnips in CM-amended soil. Figure 6 revealed that there was no significant difference between CM without biochar and CM with biochar. This could be due to the composition of CM, which is comprised of raw poultry manure and bedding materials such as sawdust wood shavings, grass cuttings, leaves, or rice hulls. This blend might provide an excellent source of N, P, and K to growing plants.

Acknowledgments

We thank Steve Diver and his farm crew at the University of Kentucky South Farm for maintaining the field plots. This investigation was supported by a grant from the United States Department of Agriculture, National Institute of Food and Agriculture (USDA/NIFA) to Kentucky State University under agreement No. KYX-10-18-65P Accession 1017900.

Literature Cited

Ferreira, C., F. Verheijen, K. Puga, J. Keizer, and A. Ferreira. 2017. Biochar in vineyards: impact on soil quality and crop yield four years after the application. 19th EGU General Assembly, EGU2017, Conf., Vienna, Austria, 23–28 Apr. 2017: 1600.

Fraser, B. 2010. High-tech charcoal fights climate change. Environ. Sci. Technol. 44: 548–549.

Haipeng, W., L. Cui, Z. Guangming, L. Jie, C. Jin, X. Jijun, D. Juan, L. Xiaodong, L. Junfeng, C. Ming, L. Lunhui, H. Liang, and W. Jia. 2017. The interactions of composting and biochar and their implications for soil amendment and pollution remediation: A review. Cri. Rev. Biotechnol. 37:754–764.

Lehmann, J., M.C. Rillig, J. Thies, C.A. Masiello, W.C. Hockaday, and D. Crowley. 2011. Biochar effects on soil biota - A review. Soil Biol. Biochem. 43:1812–1836.

Renner, R. 2007. Rethinking biochar. Environ. Sci. Technol. 41(17):5932–5933.

Shen, Z., A.M. Som, F. Wang, F. Jin, O. Mcmillan, and A. Al-Tabbaa. 2016. Long-term impact of biochar on the immobilisation of nickel (II) and zinc (II) and the revegetation of a contaminated site. Sci. Total Environ. 542:771–776.

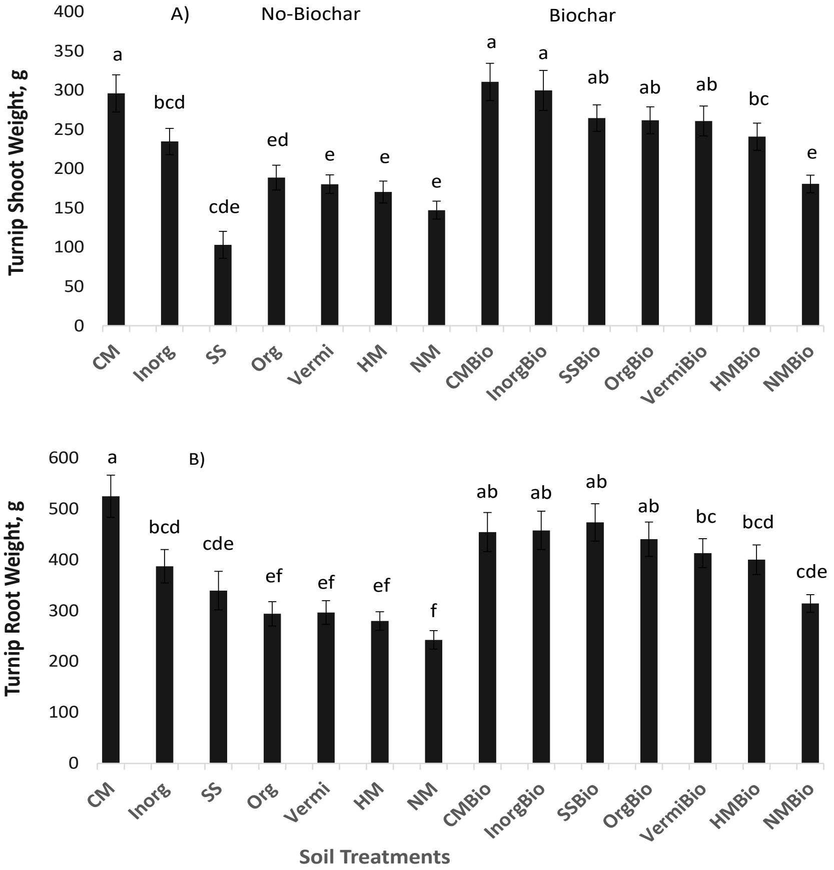


Figure 5. Average weight (n = 3) ± standard deviation of A) turnip shoot and B) root of plants grown under seven soil treatments not amended with biochar [chicken manure (CM), inorganic fertilizer (Inorg), sewage sludge (SS), organic fertilizer (Org), vermicompost (Vermi), horse manure (HM), and no-mulch (NM)] and the same seven soil treatments amended with biochar (CMBio, InorgBio, SSBio, OrgBio, VermiBio, HMBio, and NMBio), regardless of turnip variety. Statistical comparisons were carried out among soil treatments of each plant part. Bars accompanied by different letter(s) indicate significant differences ($P < 0.05$) using Duncan's multiple range test.

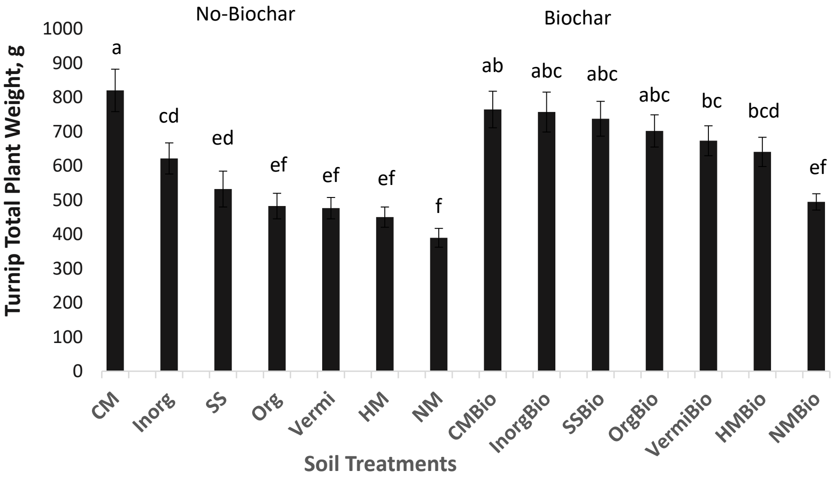


Figure 6. Average weight (n = 3) ± standard deviation of turnip plants grown under seven soil treatments not amended with biochar [chicken manure (CM), inorganic fertilizer (Inorg), sewage sludge (SS), organic fertilizer (Org), vermicompost (Vermi), horse manure (HM), and no-mulch (NM)], and the same seven soil treatments amended with biochar (CMBio, InorgBio, SSBio, OrgBio, VermiBio, HMBio, and NMBio), regardless of turnip variety. Statistical comparisons were carried out among soil treatments. Bars accompanied by different letter(s) indicate significant differences ($P < 0.05$) using Duncan's multiple range test.

Evaluation of Spring-Planted High Tunnel Lettuce Cultivars

Rachel Rudolph, Horticulture, University of Kentucky

Lettuce (*Lactuca sativa*) is an herbaceous annual crop grown primarily for consumption of the leaf blades, petioles, and stem tissue (Swiader and Ware, 2002). In terms of acreage, production, and value, lettuce is one of the leading fresh market vegetables in the United States. Lettuce is part of the sunflower family, Compositae. Looseleaf (also known as bunching), crisphead, butterhead, and romaine (also known as cos) are the four types of lettuce. Although all these types are annuals, they vary in their form and growth habits. Butterhead lettuce has smooth, soft leaves that form a loose head. It is considered to have a more delicate flavor and better table quality. Bibb is a subcategory of butterhead. Because of the delicate nature of butterhead types, they are often better suited for local markets and protected production, such as high tunnels and greenhouses. Romaine lettuce is also best for local markets. It is known to have long, narrow leaves with upright growth that forms a loose head. Spring and fall high tunnel lettuce production is particularly popular in Kentucky. New cultivars are always appearing on the market. The objectives of this trial were to evaluate the yield, head weight, and total soluble solids of early spring-planted butterhead and romaine lettuce cultivars grown in a high tunnel.

Materials and Methods

On 21 Jan. 2021, 11 lettuce cultivars (Table 1) were seeded into 50-cell trays (Landmark Plastic Corporation, Akron, OH; Vermont Compost Fort Lite, Montpelier, VT) and grown in a greenhouse on a heat mat set at 70 °F with natural light. A week before transplanting, lettuce trays were removed from the heat mat. Lettuce seedlings were transplanted on 2 Mar. 2021 inside a 30 × 96 ft high tunnel with an air-filled, 6-mil double-polyethylene layer located at University of Kentucky Horticulture Research Farm in Lexington, KY. The tunnel had previously been planted with broccoli (*Brassica oleracea*). The soil test collected before transplanting revealed a 6.45 soil pH, 148 lb/acre of phosphorus (P), 452 lb/acre of potassium (K), 4740 lb/acre of calcium, 508 lb/acre of magnesium, and 3.85% soil organic matter. The Maury silt loam soil in the high tunnel had been tilled and shaped into five slightly raised beds, approximately 2 in tall. Each plot was 5 ft long and 3 ft wide and consisted of four rows of lettuce spaced 9 in apart with two rows of drip tape (6-in emitter spacing; Aqua-Traxx, Toro, Bloomington, MN) placed in the middle of every two rows of lettuce. There was a 1-ft buffer between plots in the same bed. The trial was arranged as a randomized complete block design with five replications of the 11 cultivars. Treatment plots consisted of 24 plants with an in-row spacing of 12 in.

Plants were fertilized twice at a rate of 12.5 lb/acre of actual nitrogen (N) using potassium nitrate (13.7N–0P–46K). A single layer of row cover (1.5 oz/yd^2; Agribon, Berry Plastics, Evansville, IN) was placed over the plants for cold protection when temperatures were below 45 °F. Metal hoops spaced out across all beds supported the row cover and rock bags held the row cover down against wind. The high tunnel sidewalls were opened and the row cover removed daily if temperatures were projected to be above 45 °F. No pesticide applications were made.

We harvested the middle eight lettuce heads when they matured on 6 Apr. 2021, leaving a border on all sides of unharvested lettuce. Lettuce heads were cut right above the soil using a harvesting knife. Marketable and unmarketable lettuce were sorted based on USDA grading recommendations. Lettuce heads were considered marketable based on head size, lack of cold damage, and absence of disease or pest damage. During harvest, we observed symptoms of virus on two ‘Buttercrunch’ lettuce heads. We submitted samples to the University of Kentucky Plant Disease Diagnostic Laboratory, and lettuce mosaic virus was confirmed via enzyme-linked immunosorbent assay (ELISA) testing. Aside from the lettuce mosaic virus, no other disease was observed on the lettuce until after harvest. After all data were collected, lettuce drop was observed on several cultivars of lettuce. *Sclerotinia* sp. is the pathogen that causes lettuce drop.

We selected four lettuce heads from each plot and took the fourth leaf from the bottom of the head. These leaves were used to evaluate total soluble solids (°Brix). We put the four leaves from each plot in a sealed bag in a cooler that was stored at 40 °F for one day. We followed methods described by Kleinhenz and Bumgarner (2015) when measuring total soluble solids. All data were subjected to an analysis of variance (ANOVA) test using Statistical Analysis System (SAS) statistical software (Version 9.4; SAS Institute Inc.). Tukey was used to separate means when ANOVA tests were significant. Alpha was set at 0.05 for all data.

Results and Discussion

The majority of the lettuce cultivars were harvested within their projected days to maturity. This is probably because the air temperatures during the month of March were close to optimum for lettuce production. Optimum air temperature for lettuce development is between 60 and 65 °F. The minimum and maximum air temperatures for lettuce are generally considered 45 and 75 °F (Maynard and Hochmuth, 2007), but different cultivars may tolerate temperatures above and below. The average maximum and minimum outdoor air temperatures from 2 Mar. to 6 Apr. 2021 were 59.8 °F and 38 °F, respectively (Kentucky Mesonet, 2021). From 1991 to 2020, the monthly climatological normal temperatures in Lexington in March were 56.1 °F (high) and 35.8 °F (low; National Weather Service, 2021). Additionally, on a sunny day, the temperature inside the high tunnel can often be 20 °F higher or more than the external temperature.

Table 1. Lettuce cultivars and their characteristics, grown in a high tunnel in Spring 2021 in Lexington, KY.

Cultivar[z]	Days to maturity	Type	Description
Buttercrunch	64	Bibb	Dark green with thick outer leaves. Vigorous. Not mosaic virus tested.
Dragoon	44	Romaine (Little Gem)	Uniform compact heads with green, semi-savoyed leaf structure. Resistance to downy mildew (races 1-8, 16-27), lettuce leaf aphid, corky root rot, and lettuce mosaic virus.
Harmony	68	Butterhead	Produces large head with deep green color, smooth, glossy leaves. Intermediate resistance to bolting, tipburn, and downy mildew (races I, IIA, IIB, III, IV, V).
Marciano	60	Butterhead	Compact with smooth, burgundy leaves and bright green interiors. High resistance to downy mildew, lettuce leaf aphid, and tomato bushy stunt virus, and intermediate resistance to lettuce mosaic virus.
Milagro	60	Butterhead	Darker green heads with glossy leaves. Good for processing and packing. High resistance to downy mildew (races 1-9 and 16-35), fusarium wilt (race 1), lettuce leaf aphid, tomato bushy stunt virus, and lettuce mosaic virus.
Pomegranate Crunch	50	Butterhead-like	Open habit and smooth butterhead-like red outside leaves and red to green inside. High resistance to downy mildew 1-8, 16-27, 29 and 32 and lettuce dieback complex.
Sangria	55	Butterhead	Large round heads with smooth, bright green leaves tinged with red. Resistant to bolting and tipburn.
Stanford	50	Butterhead-Romaine	Deep red with pink midribs. Bolting tolerance. High resistance to lettuce dieback complex, downy mildew (races 1-8, 16-33) and lettuce leaf aphid.
Roxy	58	Butterhead	Loosely filled heads. Leaves red on the outside and green on the inside. Resistant to tipburn, slow to bolt. High resistance to downy mildew (races 1-6, 16, 21, 23, 32).
Truchas	48	Romaine (not quite mini)	Upright and open plant habit. Deep red leaves. High resistance to downy mildew (races 1-9 and 16-35), tomato bushy stunt virus, and lettuce mosaic virus.
Winter Density	44	Romaine	Open-heading habit with narrow, delicate leaves and thinner ribs. Heat and frost tolerant. Less susceptible to internal tipburn.

[z] All lettuce purchased from Harris Seeds (Rochester, NY) with the exception of ‘Winter Density’, which was purchased from Johnny’s Selected Seeds (Winslow, ME).

Although in this trial the calendar days were fairly accurate, calendar days to maturity can be unreliable, because they do not take the fluctuations of temperature into account. Growing degree days (GDD), also called heat units, are the accumulation of both temperature and time. Each crop requires a certain amount of heat to develop and mature. GDDs are the units used to calculate the amount of heat accumulated over time (University of California IPM, 2016). Utilizing GDDs to predict when a crop will be harvested will be more accurate and reliable for growers, regardless of temperature or season.

Table 2. Mean marketable yield, mean head weight, mean number of marketable heads, and total soluble solids of lettuce harvested from a high tunnel in Spring 2021 in Lexington, KY.

Cultivar	Mean marketable yield (lb)[z]	Mean head weight (lb)	Mean marketable head count	Total soluble solids (°Brix)
Buttercrunch	2.78 ab[y]	0.380 a	7.2 b	3.73 d
Dragoon	2.31 ab	0.289 ab	8.0 a	4.77 ab
Harmony	3.04 a	0.380 a	8.0 a	4.89 a
Marciano	2.06 bc	0.258 bc	8.0 a	4.05 bcd
Milagro	2.85 ab	0.374 a	7.6 ab	4.27 abcd
Pomegranate Crunch	2.38 ab	0.297 ab	8.0 a	4.78 ab
Sangria	2.95 a	0.360 a	8.0 a	4.07 abcd
Stanford	1.06 d	0.136 d	7.8 ab	3.93 cd
Roxy	2.37 ab	0.297 ab	8.0 a	4.63 abc
Truchas	1.37 cd	0.172 cd	8.0 a	4.14 abcd
Winter Density	3.11 a	0.382 a	8.0 a	4.85 ab

[z] Mean marketable yield is based on the harvest of eight heads from five replicates of each cultivar.

[y] Values within the same column followed by the same letter(s) are not significantly different at $P \leq 0.05$.

‘Harmony,’ ‘Winter Density,’ and ‘Sangria’ all performed well and were not significantly different from one another in yield, average head weight, head count, and total soluble solids. All three cultivars had significantly higher yields compared to Marciano,’ ‘Truchas,’ and ‘Stanford’ (Table 2). ‘Stanford’ had significantly lower yield than all other cultivars except for ‘Truchas.’ ‘Stanford’ also had the lowest average head weight compared to all other cultivars except for ‘Truchas’ (Table 2). ‘Buttercrunch’ had the lowest °Brix measurement and was significantly lower than ‘Harmony,’ ‘Winter Density,’ ‘Pomegranate Crunch,’ ‘Dragoon,’ and ‘Roxy.’ ‘Harmony’ had the highest measurable °Brix overall.

When grown in the early spring, single-cut lettuce can be fairly low maintenance. Growers who are interested in a lower maintenance cool-season crop with market potential may want to consider butterhead or romaine-type lettuce. They grow rapidly, which allows time for growers to prepare the high tunnel for another spring-planted crop, such as tomato. With the same spacing utilized in this trial (in-row of 12 in, between row of 9 in) and five to seven 3-ft-wide beds in a 30 × 96 ft high tunnel, a grower could potentially have between 1700 and 2380 plants. This estimation assumes that only 85 ft of the length of the high tunnel would be planted with lettuce.

Acknowledgments

Thanks to Ben Yates for providing technical support, assistance with trial establishment, and harvest. Thanks to Joseph Tucker, Nancy Savage, and Sean Lynch for assistance with transplanting.

Literature Cited

Kentucky Mesonet. 2021. Monthly climatological summary, Fayette County, Lexington (03/2021), (04/2021). 7 Nov. 2020. <https://www.kymesonet.org/monthly_summaries.html?county=LXGN>.

Kleinhenz, M. and N. Bumgarner. 2015. Using °Brix as an indicator of vegetable quality: Instructions for measuring °Brix in cucumber, leafy greens, sweet corn, tomato and watermelon. Ohio St. Univ. Ext. HYG-1653. 6 Nov. 2021. <https://ohioline.osu.edu/factsheet/hyg-1653>.

Maynard, D.N. and G.J. Hochmuth. 2007. Knott's handbook for vegetable growers. 5th ed. John Wiley & Sons, Inc., Hoboken, NJ.

National Oceanic and Atmospheric Administration National Weather Service. 2021. Lexington, Kentucky Monthly Climatological Normals 1991–2020. 7 Nov. 2021. <https://www.weather.gov/lmk/clilex>.

Swiader, J.M. and G.W. Ware. 2002. Producing vegetable crops. 5th ed. Interstate Publishers, Inc., Danville, IL.

University of California Agriculture and Natural Resources Integrated Pest Management. 2016. How to manage pests: degree days. 28 Oct. 2019. <http://ipm.ucanr.edu/ WEATHER/ddconcepts.html>.

Evaluation of Spring-Planted High Tunnel Kale Cultivars

Rachel Rudolph, Horticulture, University of Kentucky

Kale (*Brassica oleracea*) is a cold-hardy, non-heading cabbage that is part of the Brassicaceae family. Although it is a biennial plant, when grown for consumption and not for seed production, it is grown as an annual crop in the United States. It is grown primarily for consumption of the leaf tissue (Swiader and Ware, 2002). It can be consumed fresh (raw) or cooked and contains many nutrients. Per 100 g of edible kale, there are 2.0 g of fiber, 135 mg of calcium (Ca), 1.7 mg of iron, and 447 mg of potassium (K), which is approximately twice the amount of fiber, four times the amount of Ca, and twice the amount of K in 100 g of butterhead lettuce (Maynard and Hochmuth, 2007). Kale is often categorized into three different types—curly, lacinato, and Siberian/Russian. The objectives of this trial were to evaluate spring-planted kale cultivars grown in a high tunnel. Cultivars were evaluated based on marketable yield and total soluble solids content.

Materials and Methods

On 21 Jan. 2021, six kale cultivars (Table 1) were seeded into 50-cell trays (Landmark Plastic Corporation, Akron, OH; Vermont Compost Fort Lite, Montpelier, VT) and grown in a greenhouse on a heat mat set at 70 °F with natural light. A week before transplanting, lettuce trays were removed from the heat mat. Lettuce seedlings were transplanted on 4 Mar. 2021 inside a 30 × 96 ft high tunnel with an air-filled, 6-mil double-polyethylene layer located at University of Kentucky Horticulture Research Farm in Lexington, KY. The tunnel had previously been cover cropped with Japanese millet (*Echinochloa esculenta* (A. Braun) H. Scholz). The soil test collected before transplanting revealed a 6.82 soil pH, 170 lb/acre of phosphorus (P), 567 lb/acre of K, 4755 lb/acre of Ca, and 518 lb/acre of magnesium. The Maury silt loam soil in the high tunnel had been tilled and shaped into five slightly raised beds, approximately 2 in tall. Each plot was 5 ft long and 3 ft wide and consisted of three rows of kale spaced 12 in apart with two rows of drip tape (6-in emitter spacing; Aqua-Traxx, Toro, Bloomington, MN). There was a 1 ft buffer between plots in the same bed. The trial was arranged as a randomized complete block design with five replications of the six cultivars. Treatment plots consisted of 18 plants with an in-row spacing of 12 in.

Plants were fertilized three times at a rate of 12.5 lb/acre of actual nitrogen (N) using potassium nitrate (13.7N–0P–46K). A single layer of row cover (1.5 oz/yd^2; Agribon, Berry Plastics, Evansville, IN) was placed over the plants for cold protection when temperatures were below 45 °F. Metal hoops spaced out across all beds supported the row cover, and rock bags held the row cover down against wind. The high tunnel sidewalls were opened and the row cover removed daily if temperatures were projected to be above 45 °F. There was one application of bifenthrin (Fanfare EC, Makhteshim Agan of North America, Inc., Raleigh, NC) at the 4.5 fl oz/acre rate for management of flea beetles (Coleoptera: Chrysomelidae) and harlequin bugs (Hemiptera: Pentatomidae).

We harvested from the middle 12 kale plants, once mature, every two weeks starting on 7 Apr. and ending on 13 Aug. 2021. Kale leaves were gently broken off from the main stem. At each harvest, plants were completely stripped of leaves, except for the youngest top three leaves that are part of the growing point. Marketable and unmarketable leaves were sorted. Leaves were deemed unmarketable based primarily on pest damage.

In order to evaluate total soluble solids (°Brix), we randomly selected four leaves from each plot. We put the four leaves from each plot in a sealed bag in a cooler that was stored at 40 °F for one day. We followed methods described by Kleinhenz and Bumgarner (2015) when measuring total soluble solids. All data were subjected to an analysis of variance (ANOVA) test using Statistical Analysis System (SAS) statistical software (Version 9.4; SAS Institute Inc.). Tukey was used to separate means when ANOVA tests were significant. Alpha was set at 0.05 for all data.

Results and Discussion

The optimum air temperature for kale development is 60 to 65 °F. The minimum and maximum air temperatures for kale are generally considered 40 and 75 °F, respectively (Maynard and Hochmuth, 2007), but different cultivars may tolerate temperatures above and below. From 1991 to 2020, the monthly climatological normal temperatures in Lexington in March were 56.1 °F (high) and 35.8 °F (low; National Weather Service, 2021). For the duration of the trial, the average high and the average low outdoor air temperatures were 73.1 and 54.6 °F, respectively (Kentucky Mesonet, 2021). However, the temperatures inside the high tunnel can often be 20 °F higher or more on a sunny day, compared to external temperatures.

Table 1. Kale cultivars and their characteristics, grown in a high tunnel in Spring 2021 in Lexington, KY.

Cultivar	Days to maturity	Type	Description
Black Magic[z]	30-60	Lacinato	Dark green color with narrow, strappy leaves that are puckered. Upright growth with bolt tolerance.
Darkibor	75	Curly	Similar to Winterbor, but not as tall, later to mature, and slightly less curled. Color is darker green. Tight curl and close internodes.
Dazzling Blue	60	Lacinato	Blue leaves with purplish-pink mid-rib veins. Very cold hardy.
Redbor	75	Curly	Red and purple color. Plants grow up to 24 in tall and have an upright uniform habit. Continuously cut for yields all season.
Red Russian	25-50	Siberian/ Russian	Broad, flat green leaves with red veins and gently serrated edges. Cut Red Russian at baby size for baby mesclun mix, or harvest mature bunches.
Vates	55	Curly	Uniform with finely curled, blue-green leaves. Can last over winter if protected from severe cold and wind.

[z] All kale seed purchased from Harris Seeds (Rochester, NY) with the exception of 'Darkibor', which was purchased from Johnny's Selected Seeds (Winslow, ME).

'Red Russian' had the highest mean marketable yield (33.14 lb) and was significantly higher than all other cultivars except 'Vates' (Table 2). 'Darkibor,' 'Dazzling Blue,' and 'Black Magic' were not significantly different from one another in terms of average yield. 'Redbor' produced the lowest average yield.

Leaves are the primary site for photosynthesis and supply sugars to the rest of the plant, such as fruit and tubers. However, if the plant does not produce such organs, the leaves can accumulate sugars (Kleinhenz and Bumgarner, 2015). Although some may not immediately think of leafy greens in terms of sweetness or sugar content, their flavor is crucial for marketing and sales. The highest yielding kale cultivars measured the lowest for total soluble solids in both measurements on two different dates. In both measurements, 'Dazzling Blue' had the highest total soluble solids (8.32 °Brix; Table 2). In the first measurement, it was only significantly higher than 'Red Russian' and 'Vates.' However, in the second measurement, it was significantly higher than all other cultivars except 'Redbor' (Table 2). Throughout the season, the leaves of 'Red Russian' and 'Vates' were much larger than the other cultivars. This may be the reason for the lower °Brix values, as the sugars had to be distributed across more area. Although no taste tests were conducted, the total soluble solids measurements are helpful in indicating flavor and may be useful for growers when selecting a cultivar for their market.

When grown in the early spring, kale can be a low maintenance crop. However, as the temperatures increase, pest management can become more time-consuming. Kale is intended to be harvested multiple times and therefore, may take up precious high tunnel space that more high-value spring and summer crops may need. Growing high tunnel kale in the fall, after those high-value warm season crops are done, may be a better use of the high tunnel space and may require less management overall, with pest pressure decreasing as the temperatures decrease.

Acknowledgments

Thanks to Ben Yates for providing technical support, assistance with trial establishment, and harvest. Thanks to Joseph Tucker, Nancy Savage, and Sean Lynch for assistance with transplanting. Thanks to Maya Horvath, Victoria Bajek, and Amanda Winters for assistance with harvesting and data collection.

Table 2. Mean marketable yield and total soluble solids (TSS) of kale harvested from a high tunnel in Spring 2021 and Summer 2021 in Lexington, KY.

Cultivar	Mean marketable yield (lb)[z]	TSS 1[y] (°Brix)	TSS 2 (°Brix)
Black Magic	14.82 bc[x]	7.88 ab	10.87 b
Darkibor	19.08 b	7.45 ab	10.87 b
Dazzling Blue	15.74 bc	8.32 a	12.37 a
Redbor	12.12 c	7.84 ab	11.11 ab
Red Russian	33.14 a	6.80 b	9.99 cb
Vates	30.04 a	6.77 b	9.07 c

[z] Mean marketable yield is based on the harvest from 12 kale plants from five replicates of each cultivar.

[y] TSS 1 was measured on 8 Apr. 2021 from leaves harvested on 7 Apr.; TSS 2 was measured on 21 Apr. from leaves harvested on 20 Apr.

[x] Values within the same column followed by the same letter(s) are not significantly different at $P \leq 0.05$.

Literature Cited

Kentucky Mesonet. 2021. Monthly climatological summary, Fayette County, Lexington (03/2021), (04/2021). 7 Nov. 2020. <https://www.kymesonet.org/monthly_summaries.html?county=LXGN>.

Kleinhenz, M. and N. Bumgarner. 2015. Using °Brix as an indicator of vegetable quality: instructions for measuring °Brix in cucumber, leafy greens, sweet corn, tomato and watermelon. Ohio St. Univ. Ext. HYG-1653. 6 Nov. 2021. <https://ohioline.osu.edu/factsheet/hyg-1653>.

Maynard, D.N. and G.J. Hochmuth. 2007. Knott's handbook for vegetable growers. 5th ed. John Wiley & Sons, Inc., Hoboken, NJ.

National Oceanic and Atmospheric Administration National Weather Service. 2021. Lexington, Kentucky Monthly Climatological Normals 1991–2020. 7 Nov. 2021. <https://www.weather.gov/lmk/clilex>.

Swiader, J.M. and G.W. Ware. 2002. Producing vegetable crops. 5th ed. Interstate Publishers, Inc., Danville, IL.

University of California Agriculture and Natural Resources Integrated Pest Management. 2016. How to manage pests: degree days. 28 Oct. 2019. <http://ipm.ucanr.edu/ WEATHER/ddconcepts.html>.

Eastern Kentucky Watermelon Variety Trial

*Shawn Wright, Horticulture, University of Kentucky; Wyatt Lucas, RCARS Intern, University of Kentucky;
David Neace, Horticulture, University of Kentucky*

Watermelon, seeded and seedless (triploid), is one of the most commonly planted vegetable crops in Kentucky. While much of the production is marketed directly to consumers, there is some wholesale production from the areas of concentrated production, which include Allen, Casey, Christian, Daviess, Hart, Lincoln, Scott, Taylor, and Todd counties (Saha et al., 2016). Variety selection is one of the primary decisions for farmers considering yield, disease resistance, and fruit characteristics. While much of the watermelon production in Eastern Kentucky has been seeded, there has been a trend toward increasing production of triploid watermelon in the region. Seeded watermelons have two sets of chromosomes (diploid) and produce hard, black seeds, whereas seedless watermelons have three sets of chromosomes (triploid) and produce sterile, white, soft seeds. In the United States overall, seedless (triploid) watermelon shipments increased 34% in eleven years from 2003 to 2014 and was almost 85% in 2014 (Agriculture Marketing Resource Center Ag, 2021). The objective of the experiment was to evaluate nine seedless and seven seeded watermelon varieties produced under local conditions in Eastern Kentucky.

Materials and Methods

Experimental Site

A field experiment was conducted from May to Sept. 2021 at the Robinson Center for Appalachian Resource Sustainability (37.53°N 83.36°W; Elev. 688 ft), located in Jackson, KY. The soil type is Nolin-Grigsby complex silt loam (well drained, 0%–3% slope, occasionally flooded; USDA, 1998)

Experimental Design and Treatments

A randomized complete block design (RCBD) with four replications was used for both seeded and seedless melons (Table 1), with four fruit collected from each plot (16 fruit/entry) used as the experimental unit for evaluations.

Seedling and Field Preparation

Seeds of triploid melons were sown the week of 3 May 2021. Seeds were sown into 50-cell polyethylene transplant trays (Johnny's Selected Seeds, Winslow, ME) filled with commercial soilless mix (Pro-Mix, Quakertown, PA). Triploid melons were placed on a Jump Start seedling heat mat for 3 days and covered with black plastic until the first seedlings emerged. Seeded melons and the pollenizer 'Ace' were seeded the week of 10 May the same way, but a heat mat was not used. Plants were held under greenhouse conditions (24 °C low and 30 °C high temperatures). Trays were placed on screened racks outside the greenhouse one week prior to transplanting. All plots were planted between 29 May and 1 June.

Granular fertilizer (19–19–19) was incorporated into the beds before laying black polyethylene plastic (.70 mm-thick, high-density plastic film, 1.2 m wide) at a rate of 3106 kg/ha. Ethalfluralin (1.13 A.I. lb/acre) and clomazone (0.15 A.I. lb/acre) were applied in the spray lane dividing the field prior to transplanting for initial weed control, and the spray lane was mowed later in the season as needed. Teff [*Eragrostis tef* (Zuccagni) Trotter] was sown at a rate of 33.6 kg/ha for weed control between the beds 2 weeks after transplanting.

Crop Production

Rows were 3 m on center with 2.4 m alleyways (edge of bed to edge of bed). In-row plant spacing was 0.6 m for triploid melons and 1.2 m for seeded melons. Plots were one row and 6.1 m long, with 11 triploid or 6 diploid plants to be grown for each experimental plot. Plots with missing transplants were replanted 7 days after planting to achieve a 100% stand count. Trickle irrigation was used over the course of the season as needed, and fertigation was started 2 weeks after planting and was drip-applied on 2 June and 23 June using calcium nitrate (1.7 kg/ha). Total fertilizer applied through fertigation over the season was 3.5 kg/ha calcium nitrate.

A conventional fungicide spray program for Kentucky watermelon production was used (Rudolph et al., 2019). Fungicides were applied starting 24 June and continuing through 6 Aug. at intervals of 7 to 14 days. The first and fourth applications were pyraclostrobin (Pristine BASF) at 12.5 oz/acre, and dimethomorph and ametoctradin (Zampro BASF) at 14 oz/acre. The second application was pyraclostrobin at 12.5 oz/acre. The third and fifth applications were azoxystrobin (Quadris Syngenta) at 11 oz/acre. Permethrin (Permethrin 3.2 EC) was applied at 1 oz/acre on 24 June for squash bug (*Anasa tristis*) management.

Pollenizer Plants

The diploid pollenizer 'Ace' was interplanted after triploid plants 4 and 7 in each plot. Two hives of bees were 20 meters to the east of the planting, but one hive weakened during the season and was dead by harvest time.

Crop Harvest and Data Collection

Watermelon harvest began 29 July and ended 20 Aug. For triploid melons, the first four ripe melons from a plot were weighed, cut in half and rated visually for severity of hollow heart and rind thickness measured at opposite points. Hollow heart is a physiologic disorder where the flesh separates in the fruit. Total soluble solids readings were collected on flesh from the heart of the melon using a handheld refractometer (Spectrum Technologies, Aurora, IL). Flesh firmness was determined using a penetrometer FT 011 (range: 1–11 lb/4.4–44 Newtons) with a 1.11 cm-diameter plunger tip (QA Supplies LLC, Norfolk, VA). Penetrometer measurements were collected from two locations equidistant between the heart and the rind. The bottom half of the melon was then cut in half and the black seeds were counted on the cut surface. Evaluations for the seeded melons were identical, except no count of black seeds was done. Data were analyzed using SAS (version 9.3, SAS Institute, Cary, NC) ANOVA, and when interaction was observed, means separation using SLICES was performed. Seedless and seeded melons were analyzed separately.

Results and Discussion

Seedless

For seedless melons, there was significant block by variety interaction for all variables.

'Lynx' had no black seeds in any of the 16 melons sampled. Black seeds averaged less than one total per three cut surfaces on a melon quarter for 'Cheetah,' 'Extazy,' 'Leopard,' 'Nectaro,' and 'Ocelot.' 'Sirius' averaged less than one seed per three cut surfaces in the first three blocks. 'Sirius' in Block 4 had one melon with five black seeds, an average of 1.75 hard seeds per fruit, and an overall average of 0.75 across blocks. 'Gentility' had two blocks (Block 2 and Block 4) that averaged more than one seed per three cut surfaces, and one melon had five hard seeds, with an overall average across all blocks of one hard seed per melon. 'Tigris' only had one black seed in the first three blocks. However, Block 4 had one melon with 21 black seeds and an overall average across blocks of 1.6 seeds per melon. Block 4 was the source of the block by variety interaction, and if it was not included in the analysis, 'Gentility' would have been the only variety that had an average of more than one hard seed per melon in any block.

Hollow heart was rated visually on a scale of 1 (no hollow heart) to 5 (severe hollow heart). 'Cheetah,' 'Extazy,' 'Leopard,' 'Nectaro,' 'Ocelot,' and 'Tigris' had no hollow heart in the 16 melons evaluated. 'Sirius' had one melon in Block 1 rated as 2 (slight) and one melon in each of Blocks 1 and 4 rated as 3 (moderate), for an average rating of 1.3. 'Gentility' had one melon in Block 4 rated as 3 and one melon rated as 4 (significant) for an average rating of 1.3. 'Lynx' had 11 melons with hollow heart and seven of those rated as 3 or higher, with an average rating of 2.4. Block 3 was the only block that had no melons with hollow heart across all varieties.

Rind thickness for seedless melons ranged from 7 to 24 mm. 'Gentility' consistently had the lowest average rind thickness in all blocks, ranging from 7.0 to 9.1 mm. 'Lynx' and 'Extazy' consistently had the greatest average rind thickness (> 15 mm) in all blocks, ranging from 15.0 to 18.5 mm. The average rind thickness of 'Cheetah,' 'Nectaro,' and 'Ocelot' was greater than 11.0 mm and less than 15.0 mm in all blocks. 'Tigris,' 'Sirius,' and 'Leopard' had some blocks in which the average rind thickness was greater than 15.0 mm and some blocks in which the average rind thickness was less than 15.0 mm.

Average fruit firmness for seedless melons ranged from 8 to 17.3 Newtons. 'Cheetah' and 'Ocelot' were consistently in the highest average mean grouping across all blocks and averaged from 13.8 to 15.6 Newtons. No consistent pattern was found for other varieties across blocks.

When individual blocks were analyzed using SLICES, there was no significant difference in average seedless melon weight in Block 1. In Blocks 2, 3, and 4, there were significant differences in means grouping (n = 2–4) and in the placement of the varieties within means grouping. The consistent trends across Blocks 2 through 4 were for 'Tigris' to be in the heaviest average mean grouping and for 'Lynx' and 'Ocelot' to be in the lowest average mean grouping. Average mean weight across blocks ranged from 2.37 to 5.20 kg.

Average total soluble solids ranged from 10 to 14 °Brix across blocks. 'Gentility' was consistently in the highest average mean group, and 'Tigress' was consistently in the lowest average mean group. No other consistent patterns for varieties existed across blocks.

Table 1. Varieties and seed sources of watermelons in the 2021 cultivar trial at the Robinson Center for Appalachian Resource Sustainability in Jackson, KY.

Cultivar	Seed Source
Pollinator	
Ace	Johnny's Selected Seeds
Seeded	
Sangria	Seedway
Walker	Seedway
SSX8585	Clifton Seed Company
Stargazer	Rupp Seeds
Sweet Fashion	Holmes Seed Company
Sweetheart	Seedway
Top Gun	Clifton Seed Company
Seedless	
Cheetah	Seedway
Extazy	Rupp Seeds
Gentility	Johnny's Selected Seeds
Leopard	Seedway
Lynx	Harris Seeds
Nectaro	Seedway
Ocelot	Seedway
Sirius	Rupp Seeds
Tigris	Seedway

Table 2. Total soluble solids (TSS) for seeded watermelon grown in 2021 in Jackson, KY.

Cultivar	TSS (°Brix)	Mean Grouping[z]
Sweet Fashion	12.5	A
Sangria	12.4	AB
Stargazer	12.2	ABC
SSX8585	11.8	ABC
Sweetheart	11.7	BC
Top Gun	11.6	C
Walker	10.7	D

[z] Varieties followed by the same letter are not significantly different at $P < 0.05$.

Table 3. Seedless watermelon weight range from a watermelon cultivar trial conducted in 2021 in Jackson, KY.

Cultivar	Min. - max. weight (kg)
Ocelot	0.95 - 4.73
Lynx	0.36 - 3.82
Sirius	1.08 - 4.75
Extazy	1.68 - 6.03
Gentility	0.89 - 5.52
Nectaro	1.65 - 6.24
Leopard	0.53 - 5.60
Cheetah	0.96 - 4.99
Tigris	1.37 - 6.22

Table 4. Seeded watermelon weight range from a watermelon cultivar trial conducted in 2021 in Jackson, KY.

Cultivar	Min. - max. weight (kg)
Sangria	2.45 - 14.13
Stargazer	2.97 - 18.25
SSX8585	3.07 - 14.16
Sweetheart	4.80 - 15.54
Sweet Fashion	4.57 - 17.80
Top Gun	4.41 - 15.45
Walker	6.05 - 16.05

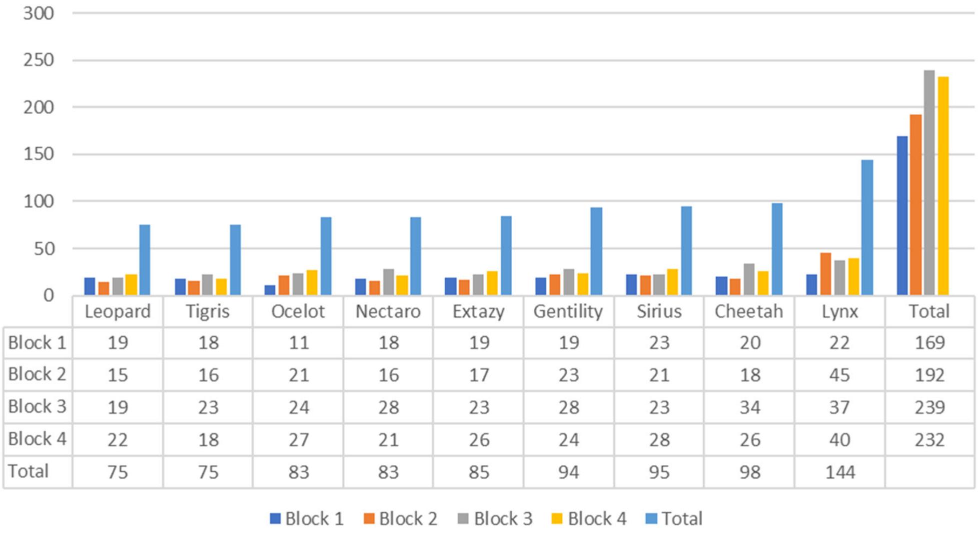
There was significant block*variety interaction for seedless watermelon count. Total watermelons ranged from a low of 75 ('Leopard' and 'Tigris') to a high of 144 ('Lynx'; Figure 1). There was also significant block*variety interaction for total seedless watermelon weight. Total watermelon weight ranged from a low of 216.60 kg ('Leopard') to a high of 292.92 kg ('Tigris'; Figure 2). Seedless watermelon weights ranged from 0.36 kg ('Lynx') to 6.24 kg ('Nectaro'; Table 3).

Seeded

For seeded melons, there was significant block*variety interaction for all variables except total soluble solids.

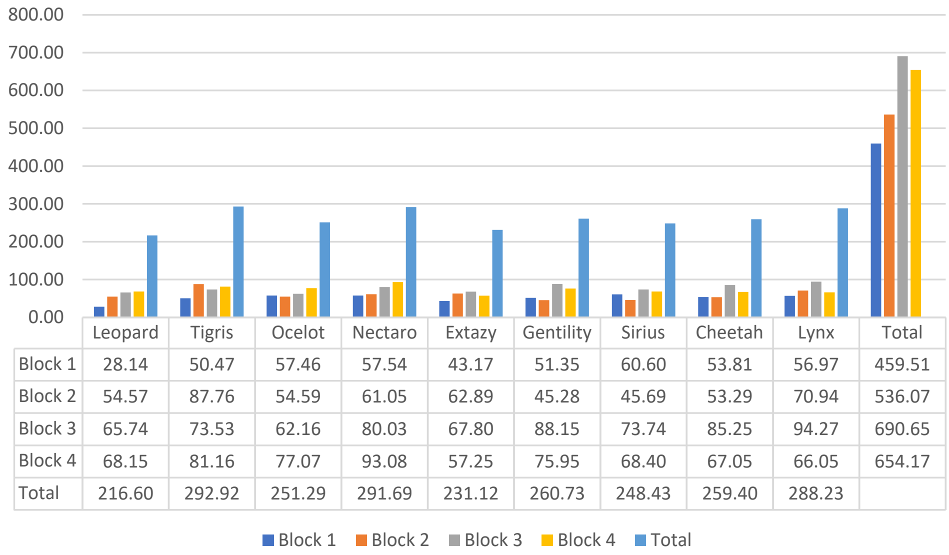
Hollow heart was rated on a scale of 1 (no hollow heart) to 5 (severe hollow heart). 'Sangria,' 'SSX8585,' and 'Sweetheart' had no hollow heart in the 16 melons evaluated. 'Walker' had an average rating of 1.1, with only one melon rated as 2 (slight). 'Stargazer' had an average rating of 1.3, with no melons rated higher than 2. 'Sweet Fashion' had an average rating of 1.4 and had one melon rated as 3 (moderate). 'Top Gun' had an average rating of 1.75 and had two melons rated as 3. Across seeded varieties, more than 97% of the melons had no or slight hollow heart.

Rind thickness for seeded melons ranged from 8–25 mm. There was no significant difference in rind thickness in Block 1. Average rind thickness across all blocks ranged from 13.0–18.8 mm.



	Leopard	Tigris	Ocelot	Nectaro	Extazy	Gentility	Sirius	Cheetah	Lynx	Total
Block 1	19	18	11	18	19	19	23	20	22	169
Block 2	15	16	21	16	17	23	21	18	45	192
Block 3	19	23	24	28	23	28	23	34	37	239
Block 4	22	18	27	21	26	24	28	26	40	232
Total	75	75	83	83	85	94	95	98	144	

Figure 1. Total marketable seedless watermelon count (n = 11) from a cultivar trial conducted in Jackson, KY, in 2021.



	Leopard	Tigris	Ocelot	Nectaro	Extazy	Gentility	Sirius	Cheetah	Lynx	Total
Block 1	28.14	50.47	57.46	57.54	43.17	51.35	60.60	53.81	56.97	459.51
Block 2	54.57	87.76	54.59	61.05	62.89	45.28	45.69	53.29	70.94	536.07
Block 3	65.74	73.53	62.16	80.03	67.80	88.15	73.74	85.25	94.27	690.65
Block 4	68.15	81.16	77.07	93.08	57.25	75.95	68.40	67.05	66.05	654.17
Total	216.60	292.92	251.29	291.69	231.12	260.73	248.43	259.40	288.23	

Figure 2. Total marketable seedless watermelon weight (kg) (n = 11) from a cultivar trial conducted in Jackson, KY, in 2021.

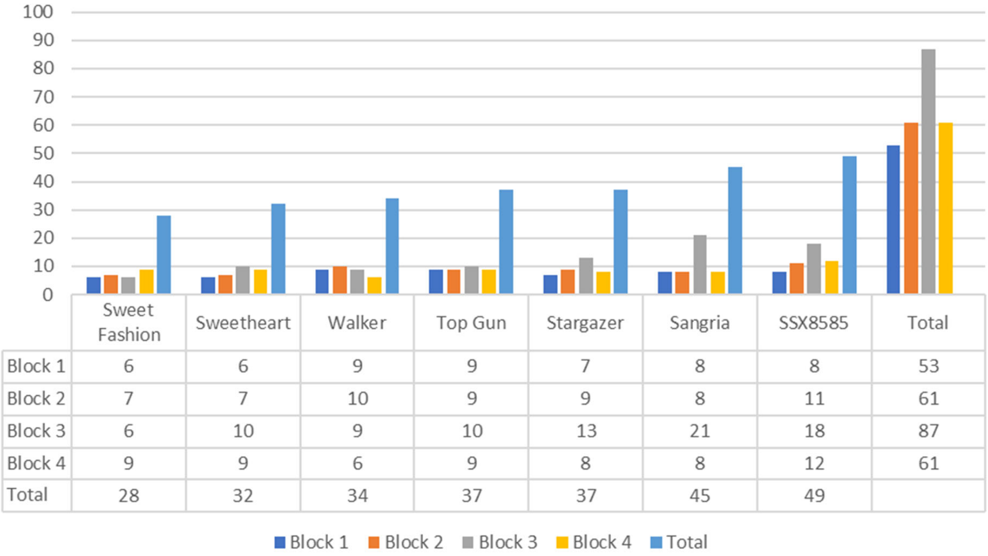
Average fruit firmness for seeded melons ranged from 1.8 – 13.8 Newtons. There was no significant difference in Block 4 when analyzed by SLICES, but 'Top Gun' consistently had the lowest average fruit firmness in Blocks 1 through 3.

When individual blocks were analyzed using SLICES, there was no significant difference in average seeded melon weight in Block 4. In Blocks 1, 2, and 3, there were significant differences in means grouping (n = 2-5) and in the placement of the varieties within means grouping, but there were no consistent trends across Blocks 1 through 3 for any varieties. Average mean weight across blocks ranged from 6.33 to 15.67 kg.

Total soluble solids were significant ($P < 0.0001$) for variety (Table 2). Mean total soluble solids for 'Walker' was the lowest (10.7 °Brix) and significantly different from the rest. Means for 'Top Gun' (11.6 °Brix) and 'Sweetheart' (11.7 °Brix) were the next lowest and significantly different from 'Sweet Fashion' and 'Sangria' means. Means for 'Sweet Fashion' (12.5 °Brix), 'Sangria' (12.4 °Brix), 'Stargazer' (12.2 °Brix) and 'SSX8585' (11.8 °Brix) were not significantly different from each other. Block, and block by variety were not significant. Total soluble solids ranged from 10 to 14 °Brix across blocks.

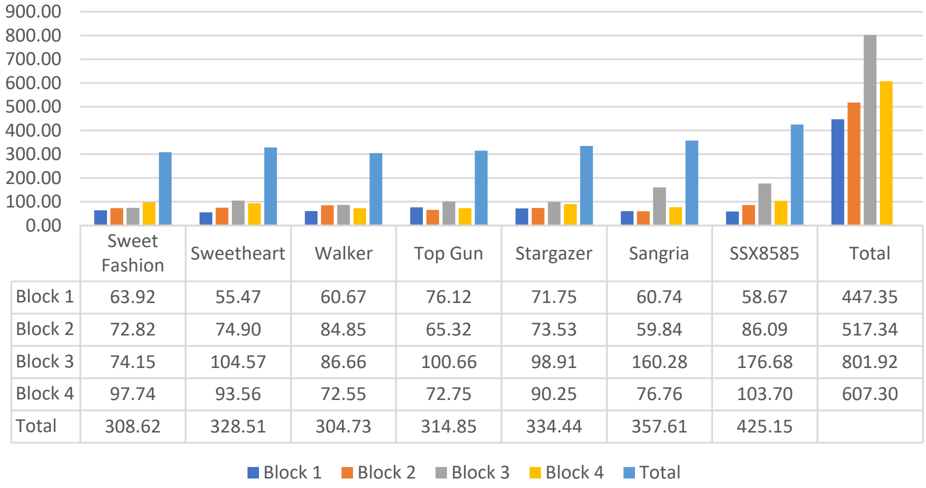
There was significant block*variety interaction for seeded watermelon count. Total melons ranged from a low of 28 ('Sweet Fashion') to a high of 49 ('SSX8585'; Figure 3). There was also significant block*variety interaction for total seeded melon weight. Total melon weight ranged from a low of 305 kg ('Walker') to a high of 425 kg ('SSX8585'; Figure 4). Seedless watermelon weight ranged from a low of 2.45 kg ('Sangria') to a high of 18.25 kg ('Stargazer'; Table 4).

While we observed trends in the trial, the block*variety interaction made evaluation of main effects impossible except for seeded watermelon total soluble solids. For growers interested in trying new varieties, it is recommended that they try several on their own farms to determine what meets their needs and serves their markets. 'Nectaro' was a seedless variety with great flavor and was one of the two most vigorous seedless watermelons based on percent germination at 10 days (data not shown). It also displayed no hollow heart. 'Top Gun' was the preferred seeded variety for flavor in an unofficial taste test performed by the harvest crew. 'Walker' was not preferred for flavor by the harvest crew and had the lowest total soluble solids compared to the other seeded varieties (Table 2). This trial should be repeated in another field that may reduce the block*variety interaction.



	Sweet Fashion	Sweetheart	Walker	Top Gun	Stargazer	Sangria	SSX8585	Total
Block 1	6	6	9	9	7	8	8	53
Block 2	7	7	10	9	9	8	11	61
Block 3	6	10	9	10	13	21	18	87
Block 4	9	9	6	9	8	8	12	61
Total	28	32	34	37	37	45	49	

Figure 3. Total marketable seeded watermelon count (n = 6) from a cultivar trial conducted in Jackson, KY, in 2021.



	Sweet Fashion	Sweetheart	Walker	Top Gun	Stargazer	Sangria	SSX8585	Total
Block 1	63.92	55.47	60.67	76.12	71.75	60.74	58.67	447.35
Block 2	72.82	74.90	84.85	65.32	73.53	59.84	86.09	517.34
Block 3	74.15	104.57	86.66	100.66	98.91	160.28	176.68	801.92
Block 4	97.74	93.56	72.55	72.75	90.25	76.76	103.70	607.30
Total	308.62	328.51	304.73	314.85	334.44	357.61	425.15	

Figure 4. Total marketable seeded watermelon weight (kg) (n = 6) from a cultivar trial conducted in Jackson, KY, in 2021.

Literature Cited

Agriculture Marketing Resource Center. 2021. Watermelon. 29 Nov. 2021. <https://www.agmrc.org/commodities-products/vegetables/watermelon>

Rudolph, R., E. Pfeufer, R. Bessin, S. Wright and J. Strang. 2019. 2020–21 Vegetable Production Guide for Commercial Growers. Univ. KY College Agr. Food Environ. Coop. Ext. Serv. ID-36. <http://www2.ca.uky.edu/agcomm/pubs/ID/ID36/ID36.pdf>.

Saha, S., J. Snyder, and J. Walsh. 2016. Kentucky Seedless Watermelon Variety Trial. Univ KY College Agr. Food Environ. Fruit Veg. 2016 Annu. Res. Rpt. PR-721: 27-29. < http://www2.ca.uky.edu/agcomm/pubs/PR/PR721/PR721.pdf >.

United Stated Department of Agriculture. 1998. Soil Survey of Breathitt County. NRCS.

Acknowledgments

The authors would like to extend their appreciation to the following for support and completion of the project: Kentucky Horticulture Council for funding; Robinson Center for Appalachian Resource Sustainability farm crew; Dr. John Strang; Tori Stanton, CAFE statistical consultant; and all the seed companies submitting varieties.

Evaluating Salt Leaching Strategies for High Tunnel Soils

Ryan Lark and Krista Jacobsen, Horticulture, University of Kentucky

High tunnels are generally defined as passively heated, semi-permanent structures consisting of a frame and polyethylene cover. As the structures exclude rainfall, supplemental irrigation is required. One of the most common irrigation methods is drip irrigation, a controlled method that delivers water directly to the soil near crop roots. This precise method can leave dry soil zones within the tunnel, preventing nutrients from leaching from the soil and subsequently accumulating over time. After a few years of usage, accumulated soluble salt levels can become problematic for farmers (Gluck and Hanson, 2013). Other nutrients such as potassium (K) are removed in large quantities with the removal of crop residue, a best practice for disease control. As a result, tunnel soils may have nutrient deficiencies. With the increasing adoption of high tunnels in Kentucky, more farmers are starting to experience these soil imbalances.

There is growing interest in methods to remediate soil salinity in high tunnels, particularly methods that allow for tunnels to remain in production. Strategies for using water to flush salts below the rooting zone ("leaching") include general recommendations like removing the plastic from the tunnel during the winter or fallow periods. Another method is to apply large quantities of water at one time through irrigation prior to planting crops. However, there is little guidance on water application rates, methods, and the subsequent effects on soil salts and crop yields. The objective of this pilot study was to evaluate the efficacy of irrigation-based leaching strategies on soil salinity and the subsequent effects on crop yield and marketability.

Materials and Methods

Experiment Site

This study was conducted during Spring and Summer 2021 in a 9 × 22 m (30 × 72 ft) high tunnel located at the University of Kentucky Horticulture Research Farm (UK HRF) in Lexington, KY. The tunnel has been certified organic according to National Organic Program guidelines since 2012 and has been covered since that time. The soil is a Maury silt loam and, prior to any treatments, was slightly acidic (pH 6.45) with elevated levels of phosphorus (P; 110 mg/kg), magnesium (Mg; 343 mg/kg), and calcium (Ca; 2382 mg/kg; Bessin et al., 2021).

Leaching Treatment

Three irrigation treatments were applied using micro-jet sprayers, applying 15 cm (6 in) or 30 cm (12 in) of water for the low and high leaching treatments, respectively, as well as a non-irrigated control. A 90° micro-jet sprayer (DripWorks, Inc., Willits, CA) was positioned in each corner of the plot, and two 180° micro-jet sprayers (DripWorks, Inc., Willits, CA) were positioned along the length. Irrigation quantities were measured using four water catchments (618 mL plastic cups) placed randomly throughout each plot and averaged to track the amount of water applied.

Irrigation treatments were randomly assigned to each plot. After the irrigation treatments were applied, each plot was randomly divided into two subplots, one with tomatoes ('Big Beef') and one fallow that would not receive a crop or irrigation throughout the crop season. The fallow subplot was included to evaluate the effects of leaching followed by lack of cropping during the growing season on soil salinity. In order to examine the effects of salt imbalances on marketable tomato yields, 'Big Beef' was chosen for the tomato subplots due to its reliable yields in organic systems as well as its susceptibility to yellow shoulder disorder (YSD) and other ripening disorders. The ratio of exchangeable K to Mg, also known as the Hartz Ratio, indicates the level of risk for YSD (Francis et al., ND). The soils at this study site were considered a medium-fine textured soil, and as such, a Hartz Ratio below 0.35 indicated a higher risk for YSD.

The study utilized a randomized complete block design with four replicated blocks. Each plot measured 2.7 × 4.9 m (9 × 16 ft) and consisted of two adjacent subplots running the length of the plot, each subplot measuring 1.4 × 4.9 m (4.5 × 16 ft). Each row of tomatoes within the cropped subplot contained six tomato plants on a single row running the length of the plot, with 0.6 m (2 ft) spacing between plants in the row.

Crop Management

Prior to planting, a complete organic fertilizer of 10N–1.7P–6.6K was applied (10–2–8 Nature Safe Fertilizer) along with a K soluble fertilizer of 0N–0P–43.2K (0–0–52 K_2SO_4). The fertilizer was tilled into the tomato subplots at a rate of 200 lb/acre of nitrogen (N) and 450 lb/acre of K. Fertilizer was added according to Mehlich-3 soil test results taken from three samples from 0 to 15 cm (analyzed by Waters Agricultural Laboratories, Inc., Owensboro, KY) and recommendations provided by the University of Maine High Tunnel Soil Testing program. Landscape fabric was used for weed suppression, with two lines of drip irrigation (30 cm drip spacing) applied under the landscape fabric in each crop row. Seven-week-old tomato transplants were used, and they were propagated at the UK HRF according to USDA NOP guidelines. Tomatoes were pruned and trained according to the Florida weave system once per week, beginning two weeks after transplanting. Irrigation was applied to the tomatoes every two to three days when tensiometers indicated soil moisture reached approximately 75% field capacity in the rooting zone (-40 centibars). Municipal water was used for irrigation and had a reported alkalinity of 63.44 $CaCO_3$ and a pH of 7.6.

Soil and Water Sampling

Soil sampling was conducted three times during the study: prior to the irrigation treatments (S1), after applying the irrigation treatments (S2), and at the end of the tomato growing season (S3). Soil samples were taken from five layers through the soil profile (0–7.5 cm; 7.5–15 cm; 15–23 cm; 23–30.5 cm;

and 30.5–45 cm). Six cores were taken from each subplot, homogenized, bulked, and passed through a 2 mm sieve. All soil samples were then sent to the University of Kentucky (UK) Division of Regulatory Services Soil Testing Laboratory for testing of soil pH, water pH, buffer pH, concentrations of Mehlich-3 extractable nutrients (P, K, Ca, Mg), and soluble salts (SS).

Irrigation water quality, specifically alkalinity levels, can affect soluble salt and other soil levels. Irrigation water used for the leaching treatments was tested by the UK Division of Regulatory Services Soil Testing Laboratory and was within the desirable range for alkalinity (63.44 ppm $CaCO_3$, < 100 ppm desirable), but with a pH of 7.6, it was more basic than what is desirable (pH 5-7; Cox, 1995).

Crop Yield and Biomass

Tomato yield data were collected weekly and graded according to USDA tomato grading standard guidelines. Fruit were graded by size and quality (USDA No. 1, No. 2, or cull), with cull data evaluated for YSD and other imperfections (USDA, 1991). Plants were terminated when yields fell below 40% marketable on 18 Aug. 2021. Final plant biomass was collected from one plant per crop subplot by harvesting the aboveground portion of the plant and drying in a 50 °C drying oven until a constant mass was achieved.

Table 1. Soil pH, phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), soluble salts (SS), and Hartz Ratio for sampling date and soil depth from a high tunnel soil in Lexington, KY.

	Sampling date[z]			Soil depth				
	S1	S2	S3	0–7.5cm	7.5–15cm	15–23cm	23–30.5cm	30.5–45cm
pH	7.23 b[y]	7.22 b	7.34 a	7.67 a	7.50 b	7.23 c	7.00 d	6.91 d
P (lb/acre)[x]	220 ab	206 a	234 b	393 a	2361 b	153 c	135 c	159 c
K (lb/acre)	227 b	199 c	258 a	421 a	243 b	164 c	142 c	171 c
Mg (lb/acre)	686 a	618 b	712 a	1020 a	744 b	562 c	496 d	539 cd
Ca (lb/acre)	4764 a	4320 b	4698 a	6042 a	4976 b	4166 c	3865 c	3920 c
SS (mmhos/cm)	1.97 b	2.20 a	2.00 b	1.36 c	2.02 b	2.44 a	2.47 a	2.01 b
Hartz Ratio	0.19 b	0.17 b	0.21 a	0.29 a	0.20 b	0.15 c	0.14 c	0.16 c

[z] Sampling conducted prior to the irrigation treatments (S1), after applying the irrigation treatments (S2), and at the end of the tomato growing season (S3).

[y] Means with the same letters within the same row and measurement parameter are not significant according to Tukey's Honest Significant Difference test.

[x] Values for P, K, Mg, and Ca are provided in lb/acre equivalent. Due to irregular sampling depths, the true lb/acre would be half of the equivalent, because lb/acre assumes a soil depth of six inches.

Table 2. The *P* values of the main effects and interactions for soil potassium (K), magnesium (Mg), soluble salts (SS), phosphorus (P), calcium (Ca), and pH. Only main effects and interactions with $P < 0.05$ were considered significant.

Effect	pH	P	K	Mg	Ca	SS	Hartz Ratio
Date	0.0007	0.0007	<0.0001	<0.0001	<0.0001	0.0003	<0.0001
Treatment	0.333	0.6518	0.3565	0.4651	0.5552	0.3121	0.6235
Crop	0.9895	0.1345	0.4077	0.0018	0.026	0.0501	0.0733
Depth	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Date*Treatment	0.3794	0.3095	0.0192	0.0007	0.1586	0.0163	0.8735
Date*Crop	0.8374	0.3646	0.0032	0.2272	0.1113	0.015	0.0001
Treatment*Crop	0.5302	0.4506	0.7119	0.0011	0.1755	<0.0001	0.3002
Date*Depth	0.06	0.004	0.0018	0.0294	0.5521	0.0835	0.001
Treatment*Depth	0.9926	0.9619	0.0011	0.7265	0.9485	0.9568	0.8556
Crop*Depth	0.8335	0.6688	0.6571	0.3186	0.9575	0.9515	0.258
Date*Treatment*Crop	0.6258	0.0712	0.4472	0.7291	0.0545	0.0115	0.7843
Date*Treatment*Depth	1	0.9988	0.8215	0.8505	0.9982	0.9945	0.9986
Date*Crop*Depth	0.982	0.4693	0.0815	0.8506	0.9843	0.9993	0.0279
Treatment*Crop*Depth	0.9883	0.8647	0.9523	0.0385	0.8088	0.9743	0.7951
Date*Treatment*Crop*Depth	1	0.999	0.9985	0.9895	0.9958	1	0.9999

Statistical Analysis

All data were assessed for normality using a Shapiro-Wilk test (W > 0.80) and analyzed using a mixed model in SAS (version 9.3, SAS Institute, Cary, NC).

Results

Yield and Crop Biomass

Marketable and total crop yield did not differ by irrigation treatment (p = 0.075 and p = 0.260, respectively). While the marketable yield was not statistically significant regarding irrigation treatments, the yields were 14.2 ± 4.54 kg for the control, 11.9 ± 1.95 kg for the 15 cm treatment, and 11.3 ± 2.28 kg for the 30 cm treatment.

Average total yield was 68.5 ± 6.49 kg per 100 ft^2, with 25.4% of yields (17.4 ± 4.07 kg) graded as marketable (USDA No. 1 and No. 2), and 74.6% graded as cull (51.1 ± 0.89 kg). Within marketable yield, the average grade No. 1 and No. 2 yields per 100 ft^2 were 4.17 kg and 13.1 kg, respectively. An average of 55.7% of cull fruit presented with ripening disorders, primarily YSD, with 44.3% exhibiting lack of marketability due to scarring, excessive radial cracking, or other physical damage. The tomato plant biomass did not differ significantly between treatments at 695 g per plant (170.2 lb/1000 ft^2; 8.31 t/ha).

Soil Data

Data for P, K, Mg, and Ca values are all given in mg/kg for accuracy purposes. Soil pH, P, K, Mg, Ca, and Hartz Ratio all decreased after the leaching treatments (S1 to S2) but increased at the final sampling date at the end of the cropping season (S2 to S3). These factors were also all greater in the upper layers of soil and decreased with depth (Table 1). Magnesium levels were higher for the fallow subplots (345 ± 9.09 mg/kg) than the cropped subplots (327 ± 7.82 mg/kg; Table 2). Calcium was also higher for the subplot left fallow (2339 ± 44.7 mg/kg) than the subplot with tomatoes (2255 ± 40.2 mg/kg).

Potassium, Mg, and SS differed by sampling date by treatment (Table 2). Potassium levels did not differ by sampling date with the application of 15 cm of irrigation water (95–110 mg/

kg). With the application of 30 cm of water, K decreased from the first sampling date (S1) (124 mg/kg) to the second sampling date (S2) (93 mg/kg) but returned to S1 levels by the third sampling date (S3) (126 mg/kg). Potassium levels in the control plots (no leaching treatment) were elevated by the S3 date (152 mg/kg) as compared to previous sampling dates (S1 = 117 mg/kg; S2 = 111 mg/kg). Magnesium levels remained relatively constant over time for the 15 cm treatment (317–337 mg/kg). Similar to K, Mg in the 30 cm treatment decreased from S1 (360 mg/kg) to S2 (313 mg/kg) but returned to S1 levels by the S3 sampling date (351 mg/kg). Soluble salts remained constant in all three sampling dates for both the control (1.54–1.84 mmhos/cm) and 30 cm treatment (1.72–1.92 mmhos/cm). The 15 cm treatment increased in S2 (2.20 mmhos/cm) but returned to S1 levels (1.97 mmhos/cm) in S3 (1.92 mmhos/cm).

The presence of the tomato crop only affected soils significantly in the control (no leaching; Table 2). Magnesium levels were higher in the fallow subplot than in the tomato subplot (362 mg/kg versus 318 mg/kg, respectively) while SS were lower in the fallow than the cropped subplots (1.48 mmhos/cm versus 1.90 mmhos/cm, respectively). Hartz Ratio only differed in the fallow plot on S3, where it was higher (0.204) than the previous dates (0.149–0.166). Potassium levels were only affected at the surface soil layer (0–7.5 cm depth), with the 15 cm irrigation treatment having the lowest K level (180 mg/kg) and the control having the highest (251 mg/kg). The 30 cm irrigation treatment did not vary significantly from either the control or 15 cm treatment (200 mg/kg).

Sampling date by depth interactions were significant for K, Mg, Hartz Ratio, and P (Table 2). Mg and P were driven by depth, with levels decreasing through the soil profile (data not shown). K and Hartz Ratio only differed in the 0–7.5 cm and 7–15 cm soil layers. For both the 0–7.5 cm and 7.5–15 cm depths, K levels did not change from S1 (203 ± 13 mg/kg; 116 ± 9.14 mg/kg) to S2 (183 ± 11.5 mg/kg; 101 ± 6.39 mg/kg) but increased on S3 (246 ± 23.2 mg/kg; 148 ± 13 mg/kg). For both the 0–7.5 cm and 7.5–15 cm depths, the Hartz Ratio did not differ from S1 (0.245 ± 0.013; 0.166 ± 0.0102) to S2 (0.235 ± 0.014; 0.153 ± 0.0086), and then increased on S3 (0.301 ± 0.026; 0.206 ± 0.018).

The sampling date by treatment by crop presence interaction was significant for SS (Figure 1). Only the control group subplot left fallow differed over time. SS increased in S2 (1.85 mmhos/cm) from S1 (1.33 mmhos/cm) but returned to S1 levels by S3 (1.27 mmhos/cm). The treatment by depth by crop presence interaction was significant for Mg but was driven by depth (Figure 2). The sampling date by crop presence by depth interaction was significant for Hartz Ratio, but only the tomato subplot at the 0–7.5 cm depth on S3 was considered low risk (Figure 3).

Discussion

From a production standpoint, the two leaching treatments had no effect on total crop yield, marketable yield, or the percentage of culled fruit, including the prevalence of ripening disorders. These data indicate that although there were some changes in nutrient levels throughout the soil profile due to the irrigation treatments, they were insufficient to have an effect on tomato crop yield or quality in this study.

Soil K and Mg levels were not affected by the application of 15 cm of irrigation water, with no significant differences between S1 and S2. The 30 cm treatment decreased both K and Mg levels between S1 and S2. Since only the 30 cm treatment showed this difference, it can be inferred that 15 cm was not enough water to leach a significant amount of K and Mg in the soil, and the 30 cm treatment was sufficient. The third sam-

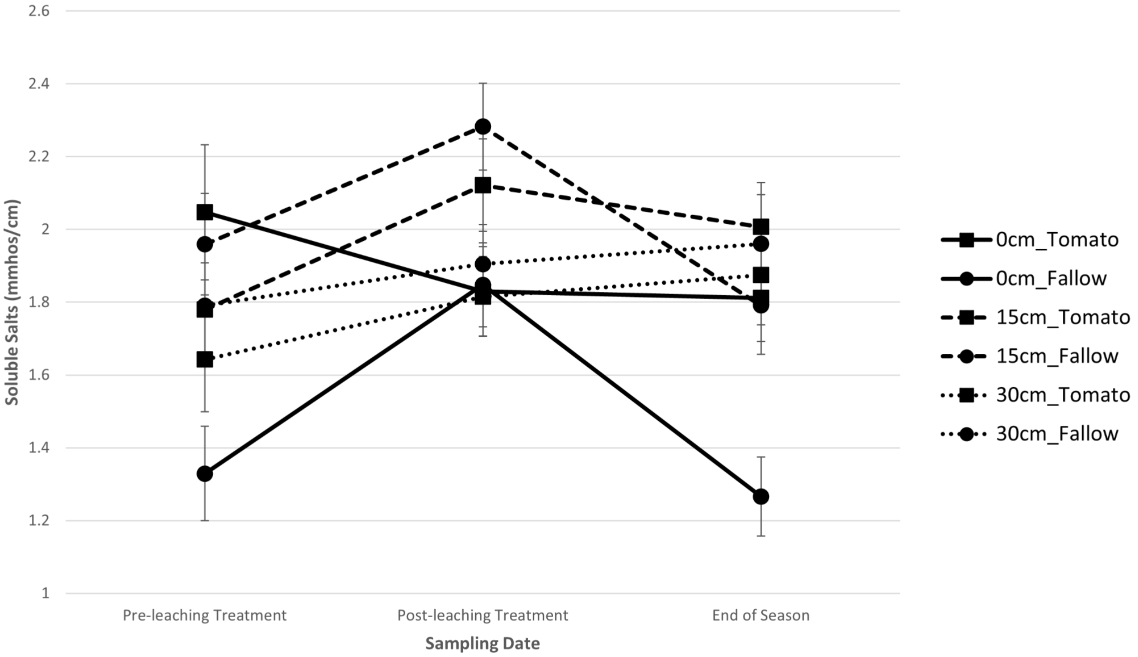


Figure 1. Soil soluble salt (SS) levels (± SE) by sampling date and presence or absence of tomato crop in response to irrigation treatment ($P = 0.0115$).

pling date saw an increase from S2 in K and Mg for both the control and the 30 cm treatment. This was probably due to the fertilizer application that occurred after the S2 sampling date and prior to the planting of the tomato crop.

All soil samples, regardless of leaching treatment, sampling date, or depth, were at risk for ripening disorders. This indicates that the leaching treatments were insufficient to leach Mg salts out of the soil profile to reduce the risk of YSD. Further, the Hartz Ratio was higher for the fallow subplot on S3 than the subplot with tomatoes. Prior to S3, the subplots did not differ. This indicates that despite high K fertilization rates used in this study, crop K uptake was greater than fertilization levels could compensate for. This, combined with low levels of Mg uptake by the crop, created soils that will be more susceptible to ripening disorders in the future.

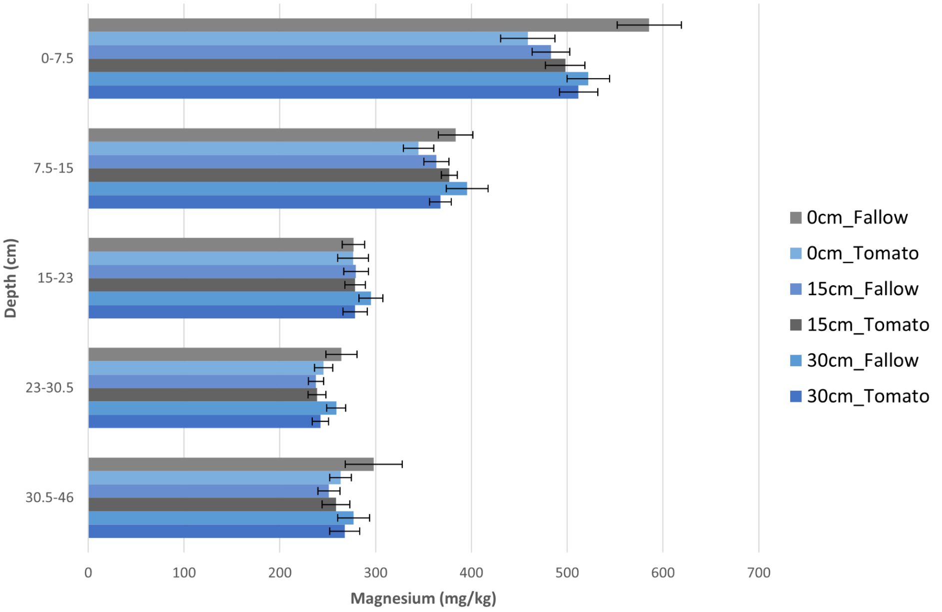


Figure 2. Soil magnesium (Mg) (± SE) by soil depth and presence or absence of tomato crop in response to irrigation treatment (*P* = 0.0385).

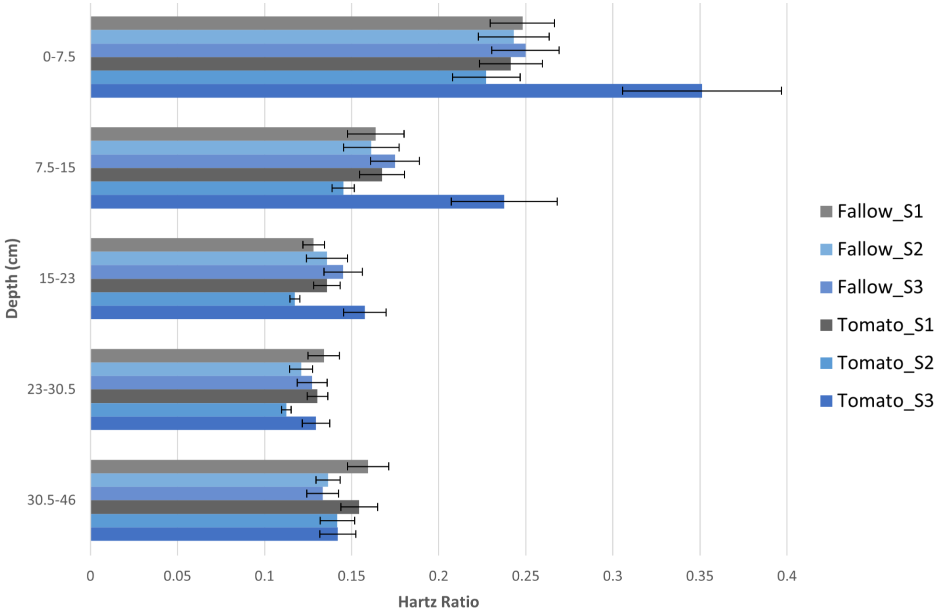


Figure 3. Hartz Ratio (± SE) by sampling date and presence or absence of tomato crop at various soil depths (*P* = 0.0279). A ratio less than 0.35 indicates higher risk for yellow shoulder disorder (YSD).

Conclusion

This pilot study demonstrated that applying 15 cm (6 in) of water does not significantly leach salts from the soil. However, applying 30 cm (12 in) did decrease K and Mg levels. However, given the imbalances of these salts prior to the irrigation treatments, no leaching treatment was sufficient to improve crop quality or yield. Future studies should research the effects of leaching strategies applying a minimum 30 cm of water on medium-textured soils with moderate salt imbalances. Additional areas of research may also include use of rainwater, surface water, or other water sources of varying water chemistries and its effect on the efficacy of leaching treatments on high tunnel soils.

Literature Cited

Cox, D. 1995. Water quality: pH and alkalinity. Univ. of MA Ext., Dept. of Plant and Soil Sci. 16 Oct. 2021. <https://ag.umass.edu/greenhouse-floriculture/fact-sheets/water-quality-ph-alkalinity>.

Francis, D., T. Sporleder, S. Garrison, C. Gunter, A. Handa, T. Hartz, and M. Foolad. ND. “Hartz” Ratio. The Ohio State Univ. 20 Oct. 2021. <https://tomato.cfaes.ohio-state.edu/HartzRatioCalculator.htm/>.

Gluck, B.I. and E.J. Hanson. 2013. Effect of drip irrigation and winter precipitation on distribution of soil salts in three season high tunnels. Acta Hort. 987, 99–104.

Bessin, R., N. Gauthier, E. Fealko, R. Rudolph, and S. Wright. 2021. Vegetable Production Guide for Commercial Growers, 2022-23. Univ. KY Coop. Ext. Serv. ID-36.

United States Department of Agriculture-Agricultural Fruit and Vegetable Division. 1991. United States Standard for Grades of Fresh Tomatoes. U.S. Dept. Agr. Fruit and Veg. Div. 16 Oct. 2021. <https://www.ams.usda.gov/grades-standards/tomato-grades-and-standards/>.

Several of the research reports presented in this document were partially funded by the Kentucky Agricultural Development Board through a grant to the Kentucky Horticulture Council.

University of Kentucky
College of Agriculture,
Food and Environment

12-2021