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Strawberry Variety Evaluation, Opportunities, and Challenges of High Tunnel Production

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Strawberry (*Fragaria xananassa*) is a high-value crop cultivated in North America with an estimated value of $2.7 billion to $3.2 billion in the time period of 2016 to 2018 (USDA-NASS 2019). Annual per-capita consumption of fresh strawberries in the U.S. has gone up from 2 pounds in 1980 to 7.1 pounds in 2018 (USDA-ERS 2019). In Virginia, producers cultivate approximately 390 acres of strawberries (USDA-NASS 2017), with the City of Virginia Beach having the most concentrated production region with 30-40 acres acres under strawberry cultivation (City of Virginia Beach 2020. Berry growers in the Mid-South cater to the local foods market and contribute heavily to agritourism activities (Gu, Guan, and Beck 2017). Fresh strawberry sales typically span a five- to six-week period. With a yield of 1.3 pounds per plant and with approximately 15,000 plants per acre, strawberry profit potential was estimated to be around $1,500 per acre per week (Safley et al. 2004; Ballington, Poling, and Olive 2008). There is interest in off-season strawberry production among local producers in the Mid-South (Gu, Guan, and Beck 2017).

Need for the Study

High tunnels can be used as a season extension tool for several berry crops, allowing the growers to gain an early entry into the market when berry prices are higher and when consumers are typically most excited about berry consumption and picking (Demchak 2009; Lamont Jr. 2002). These unheated passive-solar structures offer protection from unfavorable weather conditions including high wind, frost, hail, and precipitation, particularly during berry picking. There has been an increased interest in growing strawberries in high tunnels due to increasing consumer demand for fresh, locally grown produce in North America (Carey et al. 2009). High tunnel conditions can increase shelf life and berry quality as they keep precipitation away from berries, reducing disease pressure (Lamont Jr. 2009). Also the nutritional value of strawberries can be enhanced by increased temperature under high tunnels (Kadir, Carey, and Ennahli 2006). It is expected that acreage under high tunnels will grow with increasing demand for locally grown foods; however, profitability and potential berry yield will vary with variety choice, geographic location, and production management (Lamont Jr. 2009).).

There is limited information on variety choice and suitability of high tunnels for strawberry production for Virginia growers. This study was our first effort (1) to determine the suitability of select strawberry varieties new to high tunnel production in coastal Virginia and (2) to understand strawberry cultivation in the high tunnel environment in Southeastern Virginia. Here we document variety trial data and opportunities and challenges of high tunnel strawberry production learned through this trial.

Study Details

A study was established in a high tunnel at the Hampton Roads Agricultural Research and Extension Center in Virginia Beach during the 2015-16 growing season. The structure was a gothic-style, single-bay tunnel that was 150 feet long and 30 feet wide (fig. 1). Roll-up garage doors, 8 feet wide by 8 feet high, were installed in the center of each end wall to serve as entry points for machinery. For the sidewalls, the tunnel utilized a drop-down curtain system for ventilation that had a maximum opening of 5 feet. A simple winch and pulley system allowed for the opening and closing of the

curtain for environmental control. The study was set up as a randomized block design with three beds. Each bed was an experimental block of 40 feet in length, 4 inches high, and 2.4 feet wide on the bed top. Based on soil testing recommendations, limestone was applied pre-plant at 3.5 tons per acre and nitrogen fertilizer (N-P-K ratio of 34-0-0; Nutrisphere-N, Southern States Cooperative Inc., Richmond, Virginia) application was made at 55 pounds per acre. No additional phosphorus or potassium was needed. Four new strawberry varieties (table 1) from Lassen Canyon Nursery (Redding, California) — 'Lucia', 'Scarlet', 'Sweet Ann', and 'Ruby June' — were transplanted on Oct. 8, 2015, with 16 plants in each replicate, spaced 14 inches apart in a staggered manner in two rows within a bed.

Figure 1. Transplanting strawberry plants in the high tunnel. The tunnel design was gothic-style, single-bay, 150 feet long by 30 feet wide. Garage doors 8 feet wide by 8 feet high were on both ends of the tunnel. The tunnel could be entirely secured by closing the garage doors and rolling up the side curtains using a winch system. (Photo by J.B. Samtani.)

Table 1. Different strawberry varieties of the Lassen Canyon breeding program and their characteristics as described by Lassen Canyon Nursery (2020).

Variety	Characteristics
Sweet Ann	Day-neutral, high productivity, good flavor and size, disease resistant, few runners
Scarlet	High yield potential, firm but the inner color is light, June bearing
Ruby June	Compact, early yielding, very dark exterior and interior color
Lucia	Fruits are uniform and quality as good as Sweet Ann

Beds were drip irrigated when required. For frost protection, floating row covers (0.6 ounce) were used to cover the beds when air temperatures were predicted to drop to 35 F or lower based on information from the local weather channel (www.weather.com; fig. 2). This occurred only once that season on April 9, 2016.

Figure 2. Floating row covers were used in the high tunnel as a means of frost protection on April 9, 2016, when air temperatures were predicted to drop below 35 F. (Photo by J.B. Samtani.)

Hand weeding in the furrows and beds was done as needed. Runners on the crop plant were removed as needed. Spring fertigation for strawberries consisted of alternating calcium nitrate and potassium nitrate to provide 5.25 pounds of nitrogen per acre per week. The weekly fertigation program began at the end of March and ended in the first week of June. Generally, the ventilation curtains remained open during the winter when temperatures in the tunnel reached 70 to 75 F, and they were closed at night. As the growing season progressed into spring and summer, the curtains remained open even at night except during forecasts of high wind (>28 mph) or rain.

Yield data were collected from Dec. 31, 2015, through June 14, 2016. At each harvest date, berries were sorted into marketable and nonmarketable yield, with the marketable fruit weighing 10 grams per berry or more, without blemish or disease. Nonmarketable fruit consisted of misshapen, diseased, animal- and insect-bitten fruit and small berries (<10 grams per berry). Marketable and nonmarketable yields for the season were calculated on a per-plant basis by adding the harvest weights for the season for each replicate and dividing them by the number of plants in each replicate. The total yield for the season on a per-plant basis was calculated by adding the marketable and nonmarketable yields per plant. Fruit diameter was recorded once a

week from April 13, 2016, through June 14, 2016, by measuring five randomly selected marketable berries and calculating an average fruit diameter for each replicate. After measurement of fruit diameter, fruits were kept in a freezer at zero degrees Fahrenheit for future measurement of degrees Brix (an indication of the fruit sugar content). To determine degrees Brix, berries were removed from the freezer, thawed, and crushed using a pestle and mortar. Berry pulp was sieved through a fine mesh, and the juice was collected in a beaker. When the temperature of the juice was approximately 68 F, the degrees Brix reading was recorded with a refractometer.

Study Findings, Opportunities, and Challenges of Tunnel Production

The maximum marketable yield in all the varieties was during April (fig. 3). 'Sweet Ann' had a greater marketable yield per plant than the other varieties (table 2). The total yield (marketable and non-marketable yield) for 'Sweet Ann' was highest but similar to 'Lucia'. 'Ruby June' and 'Scarlet' yielded the same as 'Lucia' but had lower yields than 'Sweet Ann'.

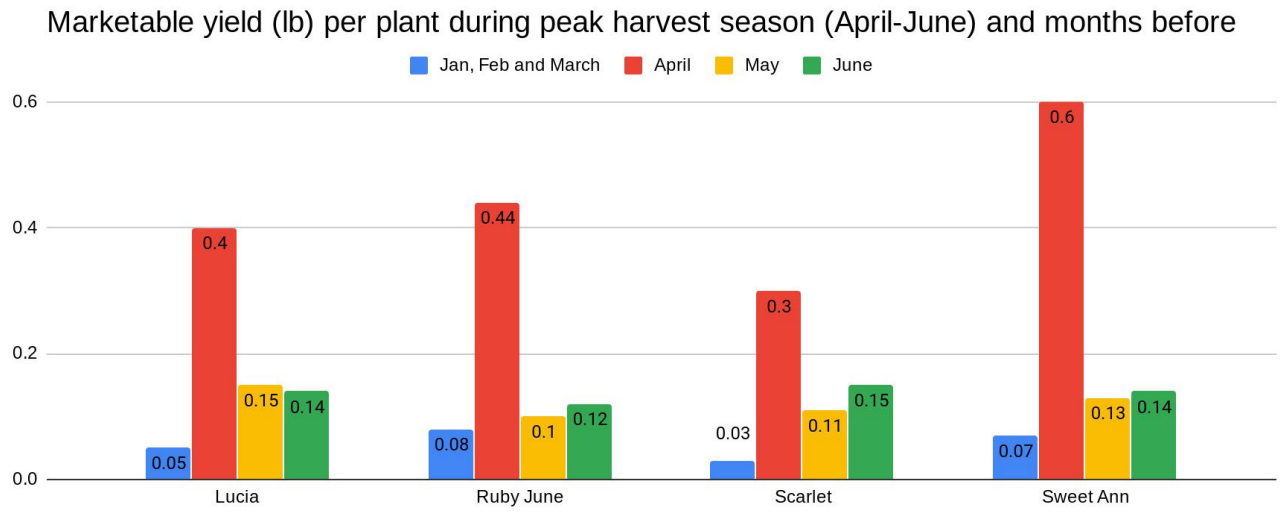

Figure 3. Marketable yield per plant of the different strawberry varieties from April through June 2016 and the three months before (January, February, and March combined). All varieties show increased yield in April. This is a month earlier than open-field production in Southeastern Virginia, which generally peaks in May.

Table 2. Yield and fruit quality of four strawberry varieties in the 2015-16 growing season in Virginia Beach.

Variety	Marketable yield per plant (lb)[a]	Total (marketable + non-marketable) yield per plant (lb)	Fruit diameter (inch)	Average (°Bx)
Lucia	0.8 b[b]	1.32 ab	1.1 b	7.4 b
Ruby June	0.8 b	1.29 b	1.3 ab	8.5 a
Scarlet	0.5 b	0.9 b	1.4 a	7.8 b
Sweet Ann	1.1 a	1.8 a	1.4 a	7.7 b

[a] If animal damage could have been controlled, yield projections could be 30% more.
[b] Means with same letter are not significantly different from one another at alpha=0.05

A standard variety such as 'Chandler' was not included with the new varieties inside the high tunnel; 'Chandler' in open-field, annual hill plasticulture can yield from 0.6 to 1.0 pound of marketable fruit per plant and is typically grown on a 6-inch-high bed. Although a higher bed would facilitate better drainage and allow for roots to penetrate deeper, the tunnel plants were grown on 4-inch-high raised beds because the smaller bed-making attachment was much easier to fit in the tunnel. The 8-feet by 8-feet openings of the garage were very tight for pulling tractor machinery and a larger bed-making machine into the tunnels. We recommend that growers install a wider and higher opening into the tunnel.

Berries from 'Scarlet', 'Sweet Ann', and 'Ruby June' plants had similar fruit diameters. The sugar content of the berries averaged for the season was highest for 'Ruby June'. Both 'Sweet Ann' and 'Ruby June' show promise for high tunnel cultivation (figs. 4, 5, and 6) due to the higher yields and sugar content of the berries.

Figure 4. 'Ruby June' strawberry variety in flower and fruit, Feb. 8, 2016. (Photo by J.B. Samtani.)

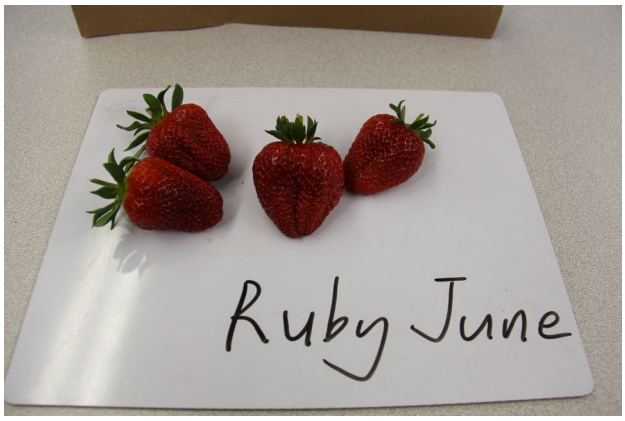

Figure 5. 'Ruby June' marketable strawberry fruits. (Photo taken March 13, 2016, by J.B. Samtani.)

Figure 6. 'Sweet Ann' marketable strawberry fruits. (Photo taken April 17, 2016, by J.B. Samtani.)

Typically, for the open-field annual plasticulture production system, the spring strawberry crop peaks in May in Southeastern Virginia. High tunnel production could provide an early extended season for locally grown produce and could potentially earn a higher market value for the crop. These additional sales could help with offsetting the costs of high tunnel construction.

Nonmarketable yield inside the high tunnel was due to animal bites; diseases including botrytis (*Botrytis cinerea*) and anthracnose (*Colletotrichum acutatum*); damage from mollusks, mites, and insects; small fruits (<10 grams in weight); and misshapen fruits. About 30% of the fruits in our study on a per-plant basis were damaged by animals. Red fox (*Vulpes vulpes*), raccoons (*Procyon lotor*), and birds entered the high tunnel and caused damage by feeding on fruits. If animal entry can be better controlled, growers can expect a higher marketable yield. Raccoons and foxes could be a potential

challenge, particularly in urban areas where food availability and food choices are scarce for these animals during winter months. For subsequent studies in the high tunnel, we installed an electric fence around the perimeter of our study area to minimize animal traffic. A bird net has also been installed along the side openings of the tunnel to prevent birds from entering the tunnel when the side curtains are open. Additionally, we have installed shade cloth on the openings of the garage doors using a wiggle wire to prevent birds from entering the tunnel when garage doors are rolled up.

Among diseases, botrytis was the major issue observed in the cooler and cloudy months of January, February, and March. In April, both botrytis and anthracnose contributed to the nonmarketability of fruits in the high tunnel. As air temperatures increased in May and June, anthracnose fruit rot was the prevalent disease issue. Additional information on these diseases, including symptoms, disease cycles, and management practices, can be found in the following publications from North Carolina State Extension:

- Botrytis Fruit Rot / Gray Mold on Strawberry – https://content.ces.ncsu.edu/botrytis-cinerea-botrytis-fruit-rot-and-blight-on-strawberry.
- Anthracnose Fruit Rot of Strawberry – https://content.ces.ncsu.edu/anthracnose-fruit-rot-of-strawberry.

Landscape fabric was used to keep the weeds in the furrows in check. Despite the use of the fabric, occasional hand weeding was necessary in furrows, ends of beds, and planting holes in order to reduce weed density. Garden slugs (*Arion hortensis*) and snails (*Cornu aspersum*) were found feeding on strawberry leaves and fruits, making irregular holes on the foliage and rendering the fruits nonmarketable. This was a particular challenge in the winter months and early spring. The use of landscape fabric created a moist environment in the furrow space that appeared to promote their reproduction. To control slugs and snails, we used slug and snail bait (1% iron phosphate) at 1 teaspoon per square yard around the planting holes, Sevin at 3/8 ounce per gallon of water, and slug traps (a plastic water bottle with a sugar-water mixture).

Twospotted spider mites (*Tetranychus urticae*) could be a potential problem for high tunnel cultivation due to dry conditions in the structures. Spider mite webs can be found mainly on the undersurface of the leaves and fruits. If heavily infested, spider mites can cause defoliation and plant death. Additional information on spider mite biology and control can be found at www.virginiafruit.ento.vt.edu/Strw2Spotted.html.

Sawfly larvae *(Empria* spp.) were another pest found feeding on the leaves of the tunnel-grown plants in February and March. Green larvae were found feeding on the leaves and usually did not require chemical treatment. Additional information on sawflies can be found on the website of University of Minnesota Extension: https://extension.umn.edu/yard-and-garden-insects/sawflies#using-pesticides-1113863.

Economic Considerations

A grower's decision on whether or not to grow strawberries in a high tunnel would be determined by the profitability of strawberry production. More elaborate variety evaluation trials at the Hampton Roads AREC in the 2019-20 growing season included both 'Ruby June' and 'Sweet Ann', and we plan to address this question of profitability for Virginia growers interested in strawberry production. This publication highlights new varieties showing promising results in our high tunnel trial and describes some of the challenges and opportunities for high tunnel production we identified through this study.

Summary

'Sweet Ann' and 'Ruby June' were the two cultivars that performed well in our trials. Growers and consumers like 'Ruby June' for its berry flavor and ease of picking as compared to other standard varieties like 'Chandler'. We were able to identify challenges as well as opportunities for strawberry production in the high tunnel environment. Challenges included a lack of preparation for a slightly different spectrum of pests, including insects, mollusks, and twospotted spider mites, as compared to open-field production. Production in the high tunnel also requires detailed weather monitoring of precipitation events, wind speeds, and high temperatures to better manage ventilation in the tunnel, which has implications on fruit disease incidences and flowering and fruiting capacity of the crop plant. Opportunities include season extension of strawberry fruit production, better management of labor at the farm during rain events, and improved fruit quality (e.g., improved fruit firmness and fewer fruit rots due to less rain exposure on the plant canopy).

Based on the information presented, we cannot say if high tunnel strawberry production is profitable. However, for growers interested in strawberry cultivation in a high tunnel, the following regional resources will be useful:

- High Tunnel Research Facility, Penn State College of Agricultural Sciences − www.youtube.com/watch?v=dPRuKE-QdnE&feature=youtu.be.
- High Tunnel Strawberries, University of Kentucky Extension publication CCD-CP-61 − www.uky.edu/ccd/sites/www.uky.edu.ccd/files/hightunnelstrawberries.pdf.

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