Raspberry Production in High Tunnels

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Fresh red raspberry consumption is growing at a high rate in the U.S. The mid-Atlantic region of the U.S. has a nearly ideal summer and autumn climate for raspberry production (relatively cool days with moderate sunlight), which makes raspberry production possible from early June to late October across the region. However, frequent rainfall during bloom and harvest reduces overall raspberry fruit quality and shelf life. Additionally, early frosts can damage or destroy late ripening varieties in the late autumn, reducing yield and shortening the season.

Most fresh market raspberries for Eastern U.S. markets are produced in California and Mexico and require considerable shipping to reach these markets. As transportation costs increase, it makes more economic sense to grow produce closer to these markets. Additionally, the increased demand for locally grown produce increases the marketing possibilities for raspberries produced in NY.

High tunnels are freestanding, plastic-covered, hoop houses used for seasonal production of many horticultural crops. There are two main advantages to producing horticultural crops under high tunnels; season extension (both early and late) and increased crop quality. In eastern production areas, rain during summer and autumn significantly reduces the quality of horticultural crops, especially of soft fruits like raspberry that have a short shelf life under the best of conditions. By keeping the rain off the flowers and fruit, shelf life in raspberry can be greatly extended to more than 10 days in some cases (Heidenreich et al., 2007). The initial cost for building tunnels can be as high as several dollars per sq. ft. when construction labor is included, which has led to more small scale adoption. The cost of high tunnels can be quickly recouped in wet years like 2006 and 2009 when there was extensive rain during bloom and fruit development. In years like this, prices are high because outside production is limited while a full crop can be harvested under tunnels turning a potentially lost harvest into superior profits.

Recent work by Dr. Marvin Pritts and others (Heidenreich et al., 2007) has demonstrated the tremendous advantages to growing raspberries under high tunnels. Fruit quality is greatly improved with larger size and much lower incidence of rot, and the season can be extended to a large extent. With appropriate varieties, the Northeastern U.S. has the potential to grow red raspberries in the field under tunnels from mid-May to mid-December. This greatly expands the season for growers so they may target a much broader market for this valuable crop.

However, little work has been done to determine which varieties are best suited for the production system or to develop new varieties specifically for this system. This project was initiated to evaluate commercially available primocane (autumn) bearing varieties and advanced selections from the Cornell raspberry breeding program for their potential in the high tunnel production system. A separate trial for floricanne varieties and selections was initiated at the same time and will be reported on at a future date.

Materials and Methods
The trial was planted at Cornell University’s New York State Agricultural Experiment Station in Geneva, NY in the spring of 2008. Dormant bare root crowns of seven commercially available varieties, ‘Joan J’, ‘Jaclyn’, ‘Autumn Britten’, ‘Polka’, ‘Himbo Top’, ‘Caroline’ and ‘Heritage’, were planted in a randomized complete block design with 3 replications/blocks. Each block was 21 ft. long with seven plants planted at 3 ft. intervals in the center of 6 in. high x 18 in. wide raised beds. The rows were spaced 8 ft. between row centers, offset to leave 4 ft. to the outside toward the tunnel legs. The three blocks corresponded to three bays in a...
multi-bay tunnel (Haygrove Tunnels, Elizabethtown, PA) that are 24 ft. wide and 120 ft. long (Figure 1). The variety trial was planted at the north end of the tunnel with open plots in the center and south end available for evaluating selections from the breeding program. Two border plants of the purple raspberry variety ‘Royalty’ were planted at the beginning of the plots on the open end of the tunnel to reduce the end effects and act as a buffer for the trial plots. The plants were allowed to grow throughout the 2008 season without the tunnel cover to allow the plots to fill in for the first production season in 2009.

Drip irrigation was provided using heavy wall 17 mm drip tubing with a capacity of 4 gph and 24 in. emitter spacing (Belle Terre Irrigation, Sodus, NY). Drip irrigation was provided one to three times per week depending on the temperature and estimated water demand with a target of 1 acre-inch per week during the growth phase and increasing to 1.5 to 2 in. per week as fruit development and harvest proceeded. A V-trellis using 8 ft. steel fence T-posts (Tractor Supply Co., Geneva, NY) and 3 levels of 2.5 mm (12 gauge, 496 lb. test) monofilament, plastic trellis wire (Amberg’s Inc., Stanley, NY) set at 2.5, 4 and 5.5 ft. above the ground. The trellis wires are anchored through cross members at the ends to 4 in. pressure treated posts sunk 4 ft. deep at approximately a 20° angle. The trellis is 18 in. wide at the top of the bed and 3 ft. wide at 6 ft.

Pest management was minimal during the season with one release of 4500 Hippodamia convergens lady bugs for a small aphid outbreak and a prophylactic release of 4000 Phytoseiulus persimilis predator mites to control any spider mites, Tetranychus urticae, in the planting (Arbico Organics, Tucson, AZ). No other pest control measures were taken during the season. Weed control was done manually with hoes and string trimmers. Glyphosate was used in aisles and along the legs to supplement the manual controls. After harvest, the plastic skin was removed, bundled and tied in the union of the tunnels for the winter to reduce insect and mite pressure in 2010 by killing exposed eggs and adults.

In April 2009, the plots were pruned to the ground to remove the 2008 growth and make room for the new primocanes for the 2009 production season. The tunnels were skinned on July 6, 2009 when the first flower buds on the new primocanes were just starting to be visible. Harvest began on August 10 and continued until October 16, 2009 (Figure 1). Fruit was harvested as often as every day depending on the temperatures and speed of ripening. Yield and the weight of a 10 fruit sample were recorded at each harvest date for each plot.

**Results**

Harvest began on August 10, 2009 with peak harvest for all varieties except Autumn Britten occurring in September (Figure 2) and continued production until mid October. Total yield across all varieties averaged 9,630 lbs. per acre with an average fruit size of 2.8 g per berry for the whole season (Tables 1 and 2). ‘Autumn Britten’ was the earliest variety by seven days and had the lowest yield at approximately 6,800 lb. per acre, equivalent to 20,360 standard 5.3 oz. (150 g) 1/2 pint units. ‘Heritage’ was the latest to begin harvest, starting on August 28. ‘Joan J’ had the highest yield with over 13,000 lbs. per acre, equivalent to almost 40,000 1/2 pint units (Table 1).

Fruit size started the season very large at nearly 4 g per berry, maintaining greater than 3 g per fruit throughout August and into September. As the season progressed, fruit size declined, averaging 2.6 g on the last harvest date and 2.8 g per berry for the entire season across all varieties (Table 2). ‘Autumn Britten’ and ‘Jaclyn’ had the largest average fruit weight over the season at 3.1 g and ‘Heritage’ the smallest at 2.1 g over the entire season. The maximum average fruit weight for any 10 fruit sample was for ‘Joan J’ on August 18 at 6.5 g per berry (Table 2). The smallest fruit was picked in a ‘Heritage’ block on September 23 averaging just 1.2 g per berry (Table 2). Overall, yields were considerably higher than yields typically observed for primocane bearing varieties grown without tunnels in Geneva, NY (Weber et al., 2004).

**Discussion**

The performance of all seven varieties was outstanding in the first season on production under high tunnels. The average overall yield of 9630 lb/acre was significantly higher than typically observed in outside production. This translates to nearly 29,000 1/2 pint units, which at $1.75 per wholesale unit is equal to a bit over $50,000 gross per acre. In a comparable trial previously performed outside, the overall yield averaged only 5,082 lb/acre in the first year of production (calculated based on 8 ft. row centers) (Weber et al., 2004), 47% lower than the tunnels.

**Table 1. Total yield and harvest dates for 7 primocane fruiting red raspberry varieties under high tunnels in 2009.**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Total Yield¹</th>
<th># standard 1/2 pint equivalents²</th>
<th>First Harvest</th>
<th>Peak Harvest³</th>
<th>Last Harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joan J</td>
<td>13,270</td>
<td>39,810</td>
<td>Aug. 17</td>
<td>Sept. 8</td>
<td>Oct. 16</td>
</tr>
<tr>
<td>Polka</td>
<td>10,364</td>
<td>31,092</td>
<td>Aug. 18</td>
<td>Sept. 14</td>
<td>Oct. 8</td>
</tr>
<tr>
<td>Caroline</td>
<td>10,358</td>
<td>31,075</td>
<td>Aug. 25</td>
<td>Sept. 15</td>
<td>Oct. 16</td>
</tr>
<tr>
<td>Himbo Top</td>
<td>8,726</td>
<td>26,179</td>
<td>Aug. 18</td>
<td>Sept. 7</td>
<td>Oct. 16</td>
</tr>
<tr>
<td>Heritage</td>
<td>7,511</td>
<td>22,534</td>
<td>Aug. 28</td>
<td>Sept. 19</td>
<td>Oct. 16</td>
</tr>
<tr>
<td>Autumn Britten</td>
<td>6,786</td>
<td>20,360</td>
<td>Aug. 10</td>
<td>Aug. 31</td>
<td>Sept. 28</td>
</tr>
<tr>
<td>Overall Means</td>
<td>9,630</td>
<td>28,890</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Yield is calculated to pounds per acre using data from 6.5 ft. of row picked in 3 replicate blocks.
² Standard weight for 1/2 pint containers is 5.3 oz. (150 g) per container equal to 3 per pound of fruit.
³ Peak harvest date is the single date with the highest daily yield.
Additionally, fruit size was significantly larger, with the overall average of 2.8g per berry in this trial compared to 1.7g in the first year of the outside trial (Weber et al., 2004). While some of this can be attributed to varietal differences, two of the varieties, ‘Heritage’ and ‘Caroline’, were common to both trials and showed similar differences.

Pest control requirements were also significantly reduced in the tunnels. No fungicides were used at any time and only spot treatments for weed control were needed. No insecticides were used at any time during the season. Even without fungicide treatments, no appreciable fruit rots were observed (Figure 3). Cull rates on fruit were so low that the data was not collected and culled fruit were not included in total yield calculations. With rates of 25% fruit rot commonly observed in outside plantings, significant improvement in the percentage of marketable fruit is easily achieved.

The only significant pest pressure on the commercial varieties in 2009 was from potato leafhoppers, *Empoasca fabae*. These insects moved into the tunnel after the first outside mowing around the outside of the tunnels and specifically targeted the varieties ‘Polka’ and ‘Jaclyn’. Significant damage was seen including stunted canes, twisted leaves and yellowing of the leaves similar to a nutritional deficiency or viral infection (Figure 4). Considerable damage was done to developing fruit at the time of infestation. The symptoms persisted throughout the season even after the insects were gone and resulted in considerable yield loss due to poorly formed fruit. The extent that the tunnel system exacerbated the leafhopper infestation or symptoms is not known but little leafhopper damage is normally observed in open production.

Another problem observed in the tunnel environment due to the growing system and not varietal differences was powdery mildew, *Podosphaera aphanis* (formerly *Sphaerotheca macularis*). This fungal disease was observed on some of the Cornell selections, but not on any of the commercial varieties. However, not all commercially available varieties have been tested in this system, and it is possible that some of them are susceptible to powdery mildew. Susceptible types show significantly more powdery mildew in tunnel conditions than outdoors to the extent that fruit is unmarketable in some cases. As new varieties are developed and released, susceptibility to this disease will need to be monitored.

Additionally, while all the varieties tested performed very well compared to outdoor conditions, many of the varieties have significant weaknesses making them less desirable for commercial production. Dark fruit color, especially after storage was observed in many varieties, especially ‘Joan J’, ‘Polka’ and ‘Jaclyn’, making them less than ideal for wholesale markets and some retail outlets. Fruit from ‘Autumn Britten’ and ‘Caroline’ could also be dark when overripe or after a few days of storage but were not as problematic as the former varieties. Darker fruit is often perceived by consumers as being overripe and having poor shelf life. This is especially problematic for red raspberries because of the relatively high cost and short shelf life compared to other fresh fruits.

The fruit firmness of ‘Joan J’ was also a mixed blessing. While the fruit can hold in cold storage for an extended period, the texture is received unfavorably by some consumers and described as “meaty” or “rubbery”. With ‘Jaclyn’ the dark fruit is especially problematic because it is very difficult to pick until it is completely ripe (when the fruit is darkest) because the receptacle is very long and thin and adheres tightly in the fruit cavity. This can cause damage when extra force is needed for picking. So, while the flavor of ‘Jaclyn’ is superior, careful consideration should be given to the color and harvest difficulty before planting this variety.

‘Himbo Top’ had some of the best fruit quality with bright, shiny red, firm fruit with good flavor. However, the plant form is much more spindly than typical primocane bearing varieties with very long fruiting laterals. This variety requires considerably more trellising that most primocane bearing varieties in order to keep the canes from weeping to the ground where the fruit can be damaged or become dirty.

‘Caroline’ performed very well but, as has been reported before (Weber, 2006), it is very vigorous with heavy foliage often obscuring the fruit and making it difficult to find to pick. This leads to unpicked ripe fruit, which then becomes overripe fruit in the next harvest. Careful and thorough picking is required to best manage this variety.

### Table 2: Mean fruit weight, maximum fruit sample weight and minimum fruit sample weights for 7 primocane red raspberry varieties under high tunnels in 2009.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mean Fruit Weight¹</th>
<th>Maximum Fruit Weight²</th>
<th>Minimum Fruit Weight³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaclyn</td>
<td>3.1</td>
<td>4.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Autumn Britten</td>
<td>3.1</td>
<td>4.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Himbo Top</td>
<td>3.0</td>
<td>4.7</td>
<td>2.1</td>
</tr>
<tr>
<td>Joan J</td>
<td>2.9</td>
<td>6.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Caroline</td>
<td>2.6</td>
<td>3.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Polka</td>
<td>2.6</td>
<td>3.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Heritage</td>
<td>2.1</td>
<td>3.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Mean fruit weight over the entire season  
² Maximum mean weight of any 10-fruit sample  
³ Minimum fruit weight of any on 10-fruit sample

Figure 3. Fruit quality of red raspberry grown under high tunnel hoop houses at Geneva in 2009 with no fungicides.

Figure 4. Leaf symptoms from potato leafhopper infestation on red raspberry.
‘Autumn Britten’ was the lowest yielding variety mainly due to low sucker development but has very good fruit quality in firmness and flavor, though it too can be dark. This variety should be planted at a higher density of no more than 2 ft. between plants to increase the fruiting cane density to increase overall yield.

‘Heritage’ performed as expected with very good cane development and fruit numbers. The round shaped fruit was typically smaller than other varieties, which reduces harvest efficiency and reduces consumer appeal. While the varieties tested did not always have optimal characteristics, the reality is that none were rejected at the wholesale level and the short supply of locally grown raspberries will probably perpetuate this situation for near future.

Conclusions
Red raspberry production under high tunnels clearly has great potential to increase yield, fruit size and fruit quality. Additionally, harvest efficiency is greatly improved through more concentrated fruit density, larger fruit size and low cull rates. These characteristics can be combined to produce superior returns to the grower. The varieties available for production have some major weaknesses but are acceptable for most markets. As new varieties are released from Cornell and other programs, the production potential will be enhanced. Tipping canes of later varieties can also push the harvest season even later into the autumn as long as temperatures can be managed, as late as early December in some cases.

The initial investment in infrastructure can be very high and learning to deal with the challenges of wind, temperature and water management and pest control in this system all warrant a measured approach in utilizing the system, but clearly the future of raspberry production in temperate regions is under high tunnels. For more information on growing raspberries under high tunnels, see the High Tunnel Raspberries and Blackberries production guide at the Cornell Fruit information website at [www.fruit.cornell.edu](http://www.fruit.cornell.edu).

Literature Cited

Courtney Weber is an associate professor in the Dept. of Horticultural Sciences who leads Cornell’s berry and plum breeding programs.