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# Primocane-Fruiting Red Raspberry Cultivar Evaluation in High Tunnels

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## Abstract

Numerous primocane-fruiting red raspberry (*Rubus idaeus*) cultivars have been introduced recently. Evaluating many genotypes for productivity and fruit quality traits is expensive and time-consuming. Here we grew 11 cultivars in containers under a high tunnel to quickly compare their performance. 'Joan J', 'Caroline', 'Himbo Top', 'Anne' and 'Josephine' were the most productive, producing 400-500 and 1,400-1,600 g per plant during year 1 and years 2-3, respectively. The earliness of ripening (earliest to latest) was 'Autumn Britten' > 'Joan J' = 'Jaclyn' = 'Himbo Top' = 'Polka' > 'Caroline' = 'Anne' > 'Josephine' > 'Joan Irene' = 'Nantahala' = 'Crimson Giant'. Following a short storage period, berries of 'Polka', 'Caroline' and 'Himbo Top' rated high in appearance, and 'Caroline', 'Jaclyn', 'Joan Irene' and 'Josephine' had lower incidences of Botrytis gray mold.


Raspberry cultivars produce fruit on current season primocanes or second year floricanes. Most recently-released cultivars are primocane-fruiting because this trait allows growers to reduce pruning costs and potentially produce raspberries even where winters are too cold to over-winter floricanes.

Newer primocane-fruiting cultivars typically are evaluated in regional field trials to identify those with commercial potential (Hanson et al., 2005; Weber et al., 2005). Cultivars perform differently in different regions, but conducting regional field trials to compare cultivars is expensive and time-consuming. Field trials are particularly hard to justify where raspberries are a minor crop, such as in the Midwestern and Northeastern U.S. Potted growing systems are being researched for commercial raspberry production (Sonsteby et al., 2013; Svensson, 2016; Qiu et al., 2016) and may offer a more rapid and convenient way of comparing genotypes than in-ground culture (Andrianjaka-Camps et al., 2015). The purpose of this work was to compare the primocane productivity and fruit quality attributes of newer raspberry cultivars using a potted growing system.

## Materials and Methods

The studies were conducted under a 7.3 x 61 x 4.3 m (W x L x H) high tunnel (Haygrove Tunnels, Inc., Redbank, Ledbury, UK) at the Southwest Michigan Research and Extension Center in Benton Harbor, MI (lat. 42.1 °N, long. 86.4 °W). The tunnel and the plant rows were oriented north to south. The tunnel was covered with Luminance THB polyethylene (BPI.Visqueen Horticultural Products, Stockton-on-Tees, UK) from late April or late May to late Oct. or early Nov. The tunnel sides and ends were left open except for approximately the last 3 weeks of the season when they were enclosed with plastic to retain heat. The experimental design was a randomized complete block design (RCBD), with eight replications (rows) in 2011 and four in 2012 and 2013, when the

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trial area was reduced to the north end of the high tunnel. Within each row, each replicate consisted of 4 plants of the same cultivar.

Dormant rooted suckers were planted in 11.4 L white polyethylene growbags (Hydro-Gardens, Colorado Springs, Colo.) in a medium composed of 70% composted pine bark (1" minus) and 30% Canadian Sphagnum peat. The primocane-fruiting cultivars 'Autumn Britten', 'Caroline', 'Crimson Giant', 'Himbo Top', 'Jaclyn', 'Joan J', 'Josephine', 'Nantahala' and 'Polka' were planted in May, 2011, and the cultivars 'Crimson Giant', 'Joan Irene', and 'Nantahala' were planted in May, 2012. Canes were removed each Dec. so that only primocane fruit were produced.

Plants were spaced 0.4 m apart in four rows that were 2 m apart. To minimize border effects, plant rows began and ended at least 6 m from the ends of the tunnel. Each row also began and ended with at least three border plants. Plants were supported by installing metal posts every 2-3 m down each row. The tops of the posts were secured to a tensioned wire running the length of each row at a height of 1.8 m. Twine was installed on each side of the plants and secured to the posts to provide support for the plants. Additional twine was installed as the plants grew in height.

Plants were drip-irrigated with one 1.9 $L \cdot hr^{-1}$ emitter per pot (Netafim USA, Fresno, Calif.). Irrigation was applied once or twice per day for 20 min early in the season and up to eight times daily during warm weather later in the season when the plant canopy was large. Plants received 45 g of Osmocote 17-5-11 fertilizer (The Scotts Company, Marysville, OH) each April. Nutrition also was applied continually through the irrigation system, using a 21-7-7 soluble fertilizer with micronutrients (JR Peters Inc., Allentown, PA) to deliver N at 100 $mg \cdot L^{-1}$.

Insecticides were applied four to eight times annually between July and Oct. to control spotted wing drosophila (*Drosophila suzukii*). No fungicides were applied.

All canes were removed in late Nov. or early Dec. and the plants were stacked two or three high in long piles in the uncovered tunnel. Each pile was then covered with a 70 $g \cdot m^{-2}$ row cover material until growth began in early or mid-April, to protect plants from winter cold. The cover was vented occasionally during warm periods earlier in the spring to keep plants from beginning growth too early.

Ripe primocane fruit were harvested on a 2–5 day schedule (26 dates in 2011, 36 dates in 2012, and 33 dates in 2013). The total weight and number of fruit were recorded on each date and used to calculate average fruit weight. Relative maturity times were compared by determining the date on which the cumulative yield from a plot exceeded 10% of the seasonal total yield for that plot. Dates were expressed as the number of days after the earliest date recorded (e.g., July 30, day 1).

Berry quality and shelf-life were compared by collecting half-pint (0.24 L) samples on selected dates when sufficient fruit was available from at least one of the replicate plots of each cultivar. A replicate consisted of a set of samples collected from a plot of each cultivar in the tunnel. Shelf-life was evaluated on five dates in 2012 and 7 dates in 2013. The number of replicate samples varied on each date. Samples were placed in half-pint clamshell containers, enclosed in sealed black plastic bags, held for 1 – 2 d in 2°C cold storage, and then moved to 18°C for 24 – 36 h. Samples were opened and given appearance ratings of 1 (not salable), 2 (possibly salable but poor quality), 3 (salable but with significant defects), 4 (good quality, only minor/subtle defects) or 5 (excellent quality, no significant defects). Characteristics detracting from quality included mold, visible juice, small or variable size, variable color, and a dull rather than glossy surface. Total fruit and number of fruit with visible mold were then counted to determine the percent with mold.

Consumer preferences were evaluated by having volunteers at a local farmers market taste several berries of each cultivar and

rate them for overall flavor, sweetness and perceived firmness on a scale of 1 (least) to 5 (most). Berries were assessed by 3 to 5 volunteers on each of six dates in 2011, by 6 to 12 volunteers on four dates in 2012, and by 2 to 11 volunteers on five dates in 2013.

Data were analyzed by year using SAS v9.4 (SAS Institute Inc., Cary, NC). The effects of treatments on yield, harvest date, consumer ratings (flavor, sweetness), and shelf-life (appearance, rot) were analyzed by analysis of variance (ANOVA) using PROC MIXED. The covariate *date* was added as a fixed effect in the model to control for the effect of date on consumer ratings and shelf-life. The response variable *rot* was log-transformed to normalize the distribution. Where variances were unequal (based on Levene's test and plots of residuals), a model with heterogenous variances was fit. Means separation was accomplished using Tukey's honestly significant differences (HSD). All statistical tests for significance were conducted at **$\alpha = 0.05$.**

## Results and Discussion

Fruit yields (Table 1) were much lower during the planting year (351 g average per plant across all cultivars) than in the second and third years after planting (1,050 and 1,190 g, respectively). Of the cultivars planted in 2011, 'Caroline', 'Himbo Top' 'Joan J' and 'Josephine' were the most productive in each of three years. 'Anne' and 'Polka' were ranked among the most productive in only one year, and 'Autumn Britten' and 'Jaclyn' were less productive in all three years. 'Joan J', 'Caroline' and 'Polka' also were the most productive of ten cultivars grown in an open field in Utah (Black et al., 2013). 'Nantahala' and 'Joan Irene' were the highest yielding of the 2012-planted cultivars, and 'Crimson Giant' was the lowest yielding cultivar. 'Crimson Giant' began fruiting too late to be productive at this site. Average yields were comparable to those of potted plants grown in a high tunnel in Switzerland (Andrianjaka-Camps et al., 2015), but about half of yields achieved in a similar system in Canada (Qiu et al., 2016).

Based on the date when 10% of the total yield was exceeded (Table 2), the earliest fruiting cultivar was 'Autumn Britten'. 'Himbo Top', 'Jaclyn', 'Joan J' and 'Polka'

**Table 1.** Primocane fruit yields of potted raspberry cultivars in a high tunnel in Benton Harbor, Mich., 2011-2013.

| | Yield (g plant$^{-1}$) | | |
|---|---|---|---|
| Cultivar | 2011 | 2012 | 2013 |
| | | Planted in 2011 | |
| Autumn Britten | 348 b[z] | 915 c | 773 e |
| Anne | 479 ab | 1205 b | 1212 bc |
| Caroline | 410 ab | 1363 a | 1237 a-c |
| Himbo Top | 413 ab | 1200 a-c | 1277 a-c |
| Jaclyn | 345 b | 876 c | 945 d |
| Joan J | 496 a | 1468 ab | 1404 ab |
| Josephine | 353 ab | 1115 a-c | 1382 a |
| Polka | 502 a | 1171 b | 994 c-e |
| | | Planted in 2012 | |
| Crimson Giant | † | 248 a | 531 b |
| Joan Irene | † | 45 b | 1016 a |
| Nantahala | † | 220 a | 1173 a |

[z] Means within columns in the same section followed by common letters do not differ at $\alpha = 0.05$ (Tukey's HSD).
† Planted in 2012; not included in 2011.

**Table 2.** Relative maturity times of primocane-fruiting raspberry cultivars expressed as the days relative to July 30 (day 1) when plots exceeded 10 % of their eventual total fruit yields.

| Variety | 2012 | | 2013 | |
|---|---|---|---|---|
| Autumn Britten | 4 | d[z] | 3 | f |
| Anne | 20 | ab | 12 | d |
| Caroline | 17 | b | 14 | cd |
| Crimson Giant | † | | 69 | a |
| Himbo Top | 9 | cd | 9 | de |
| Jaclyn | 5 | d | 9 | de |
| Joan Irene | † | | 44 | b |
| Joan J | 7 | cd | 6 | ef |
| Josephine | 25 | a | 19 | c |
| Nantahala | † | | 61 | a |
| Polka | 11 | c | 6 | ef |

[z] Means within columns followed by common letters do not differ at $\alpha = 0.05$ (Tukey's HSD).
† Not included in the trial in year indicated.

began ripening slightly later. 'Caroline' and 'Anne' began fruiting several days later, followed by 'Josephine'. 'Joan Irene', 'Nantahala' and 'Crimson Giant' began fruiting very late. Since these plants were in a high tunnel, which tends to promote earlier fruiting (Demchak, 2009; Hanson et al., 2011), plants grown without tunnels in a similar climate would likely fruit later. The order of harvest reported here is similar to that of trials containing some of the same cultivars (Hanson et al., 2011; Black et al., 2013), suggesting that the relative differences between cultivars in this potted system would be similar to that of field-grown plants. Earliness of harvest is an important trait since cultivars need to be chosen that meet desired marketing windows and do not begin fruiting too late in the fall to achieve profitable yields. The productivity of late maturing cultivars would be lower if they were grown in locations with shorter growing seasons or in open fields.

Consumer ratings of flavor were variable. The only statistically significant differences were that 'Jaclyn' rated higher in flavor than 'Autumn Britten' or 'Himbo Top' in 2011, and 'Jaclyn' and 'Josephine' were rated higher than several cultivars in 2013 (Table 3). In 2012, 'Jaclyn' also was perceived as sweeter than 'Anne', but there were no other differences between cultivars. There were no differences in consumer ratings of fruit firmness (data not shown).

To compare the shelf-life, cultivars were placed in early- or late-maturing groups so that adequate fruit were available for comparisons on common dates. The early cultivars that were rated high in appearance after a short storage period were 'Polka', 'Caroline' and 'Himbo Top' (Table 4). 'Polka' rated high because fruit had a uniform medium red color and glossy surface. The late-maturing cultivars (Table 5) had similar appearance ratings except that 'Anne' was rated higher than 'Crimson Giant' in 2013 only. The yellow-fruited cultivar 'Anne' also had a uniform size and color. 'Polka' and 'Anne' rated high in overall preference (flavor and appearance) in another study (Black et al., 2013).

Gray mold (*Botrytis cinerea*) was seldom visible on berries at harvest but developed on some fruit during storage. Early-maturing cultivars with lower incidences of mold were 'Caroline' and 'Jaclyn' (Table 4), and 'Joan Irene' and 'Josephine' had the least mold of the later maturing cultivars (Table 5).

**Table 3.** Consumer sensory appraisal of primocane fruit from raspberry cultivars in Benton Harbor, MI, 2011-2013; rating scale is 1 (least) to 5 (most).

| | Flavor (1-5) | | | Sweetness (1-5) | |
|---|---|---|---|---|---|
| Variety | 2011 | 2012 | 2013 | 2011 | 2012 |
| Autumn Britten | 2.7 b[z] | 3.1 | 2.5 c | 2.8 | 2.6 ab |
| Anne | 2.9 ab | 3.0 | 3.1 ac | 2.7 | 2.4 b |
| Caroline | 3.4 ab | 3.0 | 3.0 ac | 3.5 | 2.8 ab |
| Crimson Giant | † | † | 1.8 c | † | † |
| Himbo Top | 2.7 b | 3.3 | 3.5 ac | 2.7 | 3.0 ab |
| Jaclyn | 3.7 a | 3.5 | 3.9 a | 3.2 | 3.2 a |
| Joan Irene | † | † | 3.0 bc | † | † |
| Joan J | 3.3 ab | 3.0 | 3.3 ac | 3.3 | 2.7 ab |
| Josephine | 3.0 ab | 3.1 | 3.8 ab | 3.0 | 2.7 ab |
| Nantahala | † | † | 2.4 c | † | † |
| Polka | 3.4 ab | 3.3 | 3.4 ac | 3.3 | 3.0 ab |

[z] Means within columns followed by common letters do not differ at α = 0.05 (Tukey's HSD).
† Not included in trial in year indicated.

**Table 4.** Appearance rating (1=worst, 5=best) and percent rot of earlier-maturing primocane fruit from raspberry cultivars in Benton Harbor, MI, 2012 – 2013.

| | Appearance (1-5) | | Rotten berries (%) | |
|---|---|---|---|---|
| Variety | 2012 | 2013 | 2012 | 2013 |
| Autumn Britten | 3.4 c[z] | 3.6 b-d | 4.8 | 6.8 a |
| Caroline | 4.2 ab | 3.7 a-c | 1.1 | 0.7 b |
| Himbo Top | 3.8 a-c | 3.9 ab | 4.0 | 2.7 ab |
| Jaclyn | 3.6 bc | 2.7d | 1.3 | 2.7 ab |
| Joan J | 3.7 a-c | 3.1 cd | 1.3 | 2.3 ab |
| Polka | 4.4 a | 4.5 a | 2.8 | 2.6 ab |

[z] Means within columns followed by common letters do not differ at α = 0.05 (Tukey's HSD).

**Table 5.** Appearance rating (1=worst, 5=best) and percent rot of later-maturing primocane fruit from raspberry cultivars in Benton Harbor, MI, 2012-2013.

| | Appearance (1-5) | | Rotten berries (%) | |
|---|---|---|---|---|
| Variety | 2012 | 2013 | 2012 | 2013 |
| Anne | 3.7 | 3.5 a | 4.0 b | 2.4 bc |
| Crimson Giant | 3.7 | 2.6 b | 10.0 a | 14.1 a |
| Joan Irene | 4.0 | 3.0 ab | 1.3 ab | 0.5 c |
| Josephine | 3.7 | 3.3 ab | 2.2 b | 1.0 c |
| Nantahala | 3.9 | 3.2 ab | 11.0 ab | 6.1 ab |

[z] Means within columns followed by common letters do not differ at α = 0.05 (Tukey's HSD).

'Caroline' and 'Josephine' previously have been described as having some tolerance to gray mold (Aprea et al., 2010; Hanson et al., 2011; Harshman et al., 2014). High tunnel environments reduce gray mold incidence (Hanson et al., 2011), at least partly because rain is excluded.

## Conclusions

Raspberry cultivars were compared in a potted growing system. 'Autumn Britten' began fruiting the earliest, followed by 'Joan J' and 'Polka', 'Himbo Top' and 'Jaclyn', then 'Caroline', 'Anne', and 'Josephine'. 'Joan Irene', 'Nantahala' and 'Crimson Giant' were the latest to begin fruiting. The cultivars 'Joan J', 'Caroline', 'Himbo Top', 'Anne', 'Josephine', 'Nantahala' and 'Joan Irene' produced the highest yields. Berries of 'Polka', 'Caroline', 'Himbo Top' and 'Anne' rated highest in appearance after a short storage. 'Caroline', 'Joan Irene and 'Josephine' had lower incidences of Botrytis gray mold after storage. Results indicate a potted growing system can be used to readily compare numerous raspberry cultivars for regional performance regarding important production and quality traits. Although characteristics such as yield potential and harvest times were similar to those reported for some of the same cultivars when tested under field conditions, cultivars may respond differently under different production practices or conditions.

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