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Long-term Field Performance of Primocane Fruiting Raspberry Cultivars in New York

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SUMMARY. The performance of 11 primocane fruiting raspberry (*Rubus idaeus*) cultivars was evaluated based on yield and fruit weight from the first three seasons compared to the eighth and ninth seasons, respectively. Plot vigor and cane density was evaluated in the eighth season. 'Prelude', 'Caroline', and 'Heritage' did not show a decline in yield in the eighth season compared to the first three seasons. 'Kiwigold', 'Graton Gold' (sold as 'Goldie'), 'Watson' (sold as 'Ruby'), 'Autumn Bliss', 'Anne', and 'Amity' had substantial yield decreases from early production seasons ranging from -30% to -82%. 'Kiwigold' had the highest yield of 4015 kg·ha⁻¹ (3582.2 lb/acre) in the eighth season followed by 'Caroline' at 3649 kg·ha⁻¹ (3255.6 lb/acre), 'Heritage' at 3614 kg·ha⁻¹ (3224.4 lb/acre), and 'Prelude' at 3591 kg·ha⁻¹ (3203.9 lb/acre). Fruit weight did not vary significantly among years, but there were

differences among cultivars. In the ninth season, 'Ruby' had the largest fruit at 3.1 g (0.11 oz), followed by 'Autumn Bliss' at 2.9 g (0.10 oz), and 'Caroline' and 'Prelude' at 2.8 g (0.10 oz). 'Summit', 'Goldie', and 'Rossana' had the smallest fruit at 1.5 g (0.05 oz). 'Goldie' was the most vigorous cultivar and 'Anne' the least in the eighth season based on vigor ratings. 'Rossana' had the highest cane density at 41.6 canes/m² (3.86 canes/ft²). Seven of 11 cultivars had cane density of 32 canes/m² (3.0 canes/ft²) or higher, which is sufficient to produce acceptable yields in cultivars suited to the region. Overall, 'Prelude', 'Caroline' and 'Heritage' and its sports, 'Kiwigold' and 'Goldie', show the most potential for long production cycles in climates similar to western New York state.

Primocane fruiting raspberry (*Rubus idaeus*) cultivars have increased the acreage of red raspberry production in regions with moderately cold winter temperatures by reducing management costs, greatly reducing winter injury, and increasing the overall production window, thus making raspberries more attractive to growers. Additionally, they have expanded production into regions where low winter temperatures make commercial production of floricanes difficult due to excessive winter damage.

One of the major costs in raspberry production is the establishment of a new planting. Establishment costs are high because a minimum of 3588 plants/ha (1452 plants/acre) are required to establish an adequately productive planting (Pritts and Handley, 1989). Pre-plant operations, including cover crop rotations, drainage plan-

ning and/or soil amendments are also recommended (Pritts and Handley, 1989). Thus, no crop is harvested and no income is generated during cover crop and field establishment years. Therefore, extending the life of a planting can increase profitability by spreading out the cost of establishment over a longer production cycle and reducing the frequency of crop/income loss associated with the establishment of a new planting.

Cultivar selection may be the most important factor in ensuring the establishment and long-term productivity of a raspberry planting. Commercially available cultivars vary in vigor, disease resistance, and yield potential (Barritt et al., 1981; Goulart and Demchak, 1999; Privé et al., 1993), but no studies examining the long-term productivity of raspberry cultivars have been published. The objective of this study was to compare yield, fruit weight, and stand vigor of 11 primocane fruiting cultivars in early years of the production cycle to data from later years in the cycle to assess the potential for maintaining yield over time.

Materials and methods

Plots of 11 cultivars were established in 1994 at the New York State Agricultural Experiment Station, Cornell University, Geneva, N.Y., using a standard production system (Pritts and Handley, 1989). The cultivars included were 'Amity', 'Anne', 'Autumn Bliss', 'Caroline', 'Graton Gold', 'Heritage', 'Kiwigold', 'Prelude', 'Rossana', 'Watson', and 'Summit' (Table 1). (The cultivars 'Graton Gold' and 'Watson' are sold under their trademarked names 'Goldie' and 'Ruby', respectively.) They were planted in a completely randomized design on flat beds with five 7.6-m (25 ft) replications with 3.0 m (10 ft) between row centers and 0.9-m (3 ft) plant spacing within rows. First generation bare root suckers from certified virus indexed tissue culture stocks were used for the planting. Borders were planted at each row end and surrounding the planting to avoid edge effects.

'Amity' is an early to mid-season cultivar developed in Oregon with medium-sized fruit and some resistance to root rots (Pritts and Handley, 1989). 'Anne' (yellow fruited) and 'Caroline' were developed at the University of Maryland and produce large fruit in the late and mid-season, respectively

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Table 1. The mean and range of vigor ratings and cane density for 11 primocane fruiting raspberry cultivars in the first three production seasons and the eighth production season in Geneva, N.Y. The trial was planted at an initial density of 3588 plants/ha (1452 plants/acre) on flat beds with 3.0 m (10 ft) between row centers. The trial had five 7.6-m (25 ft) replicates, and drip irrigation was provided to supplement natural precipitation. Dead plots were scored as 1 for vigor ratings and as 0 cane density and were included in means calculation.

Cultivar	Live plots (no.) ^z	Vigor rating ^x mean (range)	Cane density (canes/m ²) ^{y, w} mean (range)
Goldie ^v	5	7.2 (6–9) a	33.8 (26–41) ab
Prelude	5	6.4 (5–8) ab	34.0 (25–39) ab
Rossana	4	6.4 (1–10) ab	41.6 (0–55) a
Kiwigold	5	5.6 (4–7) a–c	36.2 (21–42) ab
Autumn Bliss	5	5.4 (4–7) a–d	36.6 (31–45) ab
Heritage	5	5.4 (2–7) a–d	33.0 (22–42) ab
Summit	5	5.0 (2–7) a–d	31.6 (14–47) ab
Caroline	4	4.6 (1–8) a–d	29.8 (0–57) a–c
Amity	5	4.0 (3–5) b–d	21.8 (19–25) bc
Ruby ^v	3	3.2 (1–6) cd	12.8 (0–28) c
Anne	4	2.8 (1–6) d	13.8 (0–29) c
LSD _{0.05}		2.6	17.25

^zMaximum of five plots.

^vValues in the same column followed by the same letter are not significantly different at $P \leq 0.05$ according to least significant difference (LSD) test.

^yRating scale is from 1–10 with 1 = dead plot and 10 = full healthy plot.

^w1.0 cane/m² = 0.093 cane/ft².

^v‘Grafton Gold’ and ‘Watson’ are sold under their trademarked names ‘Goldie’ and ‘Ruby’, respectively.

(Goulart and Demchak, 1999). They both have good resistance to root rot caused by *Phytophthora fragariae* var. *rubi*. ‘Autumn Bliss’ is a complex hybrid from the U.K. with good resistance to root rot caused by *P. fragariae* var. *rubi*. It fruits in the early season with large fruit (Daubeny 1997). ‘Heritage’ was released from Cornell University, has medium-sized fruit, and has intermediate resistance to root rot caused by *P. fragariae* var. *rubi* (Barritt et al., 1981; Daubeny et al., 1992). ‘Goldie’ and ‘Kiwigold’ are both amber sports of ‘Heritage’ (Daubeny 1997), fruit in the late season with medium-sized fruit, and are similar to ‘Heritage’ in growth habit and performance. ‘Prelude’ was released from Cornell University and is a mid-season primocane bearer with medium fruit size (Weber et al., 2004). It has very good resistance to root rot caused by *P. fragariae* var. *rubi*. ‘Rossana’ originated in Italy, and its medium-sized fruit ripens up to 4 weeks later than ‘Heritage’ in northern climates (Daubeny 1997). It shows some resistance to root rot. ‘Summit’ originated in Oregon and is a mid-season cultivar with small to medium-sized fruit. It is resistant to root rot (Daubeny 1997).

The plots were not harvested in 1994 while the plants were establishing and filling in the row. Floricanes were

mowed to 2.5–5.1 cm (1–2 inches) aboveground before new primocanes emerged in April of each year after establishment. Pest control followed recommended practices (Pritts and Handley, 1989) for cane and fruit diseases, insect problems, and weed control.

Drip irrigation was provided to maintain a running rate that was equivalent to 3.81 cm (1.5 inches) per week [37.8 L·m⁻² (0.93 gal/ft²)] with T-tape drip irrigation [500 L·h⁻¹ per 100 m at 55.2 kPa (0.67 gal/min per 100 ft at 8 psi)] (T-Systems International, San Diego) from 15 June through the end of harvest when natural precipitation was not sufficient to reach this level. Turf was established in the row aisle using a mix of 40% perennial ryegrass (*Lolium perenne*), 30% creeping red fescue (*Festuca rubra*), and 30% hard fescue (*F. longifolia*) approximately 6 weeks after planting the raspberries. It was mowed every 7 to 10 d from May through the end of harvest. The raspberry row width was maintained at 1 m (3.3 ft). The soil type was Honeoye fine sandy loam with approximately 6% slope. Ammonium nitrate fertilizer was applied in April of each year after the establishment season at 224.2 kg·ha⁻¹ (200 lb/acre). In the November of each year, a mixture of sulfur, potassium, and magnesium

fertilizer (18.3%K–11%Mg–22%S) with 35.0 kg·t⁻¹ (70 lb/ton) of 15% borate was applied at 252.2 kg·ha⁻¹ (225 lb/acre).

To determine total yield, the center 3.0 m of each plot was harvested every 2 to 3 d beginning in mid-August until the first freeze date in 1995–97 and in 2002. From 1998 to 2001, the plots were maintained in the same manner but yield data was not collected. The final harvest date was 20, 3, 14 and 18 Oct. in 1995–97 and 2002, respectively. Mean fruit weight was calculated on three 250-fruit samples of each cultivar that were taken one week apart once sufficient berries were available in 1995–97, 2003. Fruit weight data were inadvertently not collected in 2002 and was collected in 2003 instead. An analysis of variance (ANOVA) was completed on the yield and fruit weight data followed by mean separation using least significant difference (LSD) test when significance was found following the procedures of Gomez and Gomez (1984). A *t*-test comparing the mean yield of the first three seasons and the yield of the eighth season was done following the procedures of Gomez and Gomez (1984) to compare differences between the plots after eight harvest seasons. The analysis was done on raw yield data and not on extrapolated total yields.

In the eighth season (2002), vigor of the plots was subjectively rated on a scale of 1–10 with 1 = dead plots, 3 = few living canes, 5 = moderate sucker production, 7 = heavy sucker production but with thin areas, and 10 = high cane density with no disease evident. Also, canes were counted in the center of each plot in a 1-m² (10.8 ft²) area to determine mean cane density. Dead plots were included as zero yield and zero cane density in the mean calculations and with vigor ratings of one in the analysis and not treated as missing data.

Results

Vigor ratings on the test plots ranged from completely dead (1 rating) to extremely vigorous (10 rating) (Table 1). ‘Goldie’ had the highest mean vigor rating with plots that were healthy and vigorous with sufficient cane production for good yields (Pritts and Handley, 1989) (Table 1). ‘Anne’ had the lowest rating with few canes in most plots and two plots completely dead (Table 1). ‘Prelude’, ‘Rossana’,

'Kiwigold', 'Autumn Bliss', 'Heritage', 'Summit', and 'Caroline' followed in rank, but were not statistically different from 'Goldie' (Table 1). The mean vigor rating for 'Ruby' was similar to 'Anne' (Table 1). These ratings were reflected in the cane density in the plots of each cultivar. 'Rossana' had the highest mean cane density at 41.6 canes/m² even with one plot completely dead (Table 1). 'Ruby' had the lowest cane density with 12.8 canes/m² (1.19 canes/ft²) and a maximum of 28 canes/m² (2.6 canes/ft²) in the healthiest plot (Table 1). Of the 11 cultivars, only 'Caroline', 'Amity', 'Ruby', and 'Anne' had <32 canes/m² (<3.0 canes/ft²) on average (Table 1). 'Caroline', 'Ruby', and 'Anne' also had at least one completely dead plot.

The yield of the cultivars in the eighth production season was generally lower than the average of the first three production seasons, with the exception of 'Prelude', which had a 8% increase in yield (Table 2). 'Caroline' and 'Heritage' had substantial but statistically nonsignificant yield reductions of 22% and 23%, respectively (Table 2). 'Kiwigold', 'Goldie', 'Ruby', 'Autumn Bliss', 'Anne', and 'Amity' all had significant reductions in yield ranging from -30% to -82% (Table 2). 'Summit' and 'Rossana' had commercially insignificant yields, which would not normally be harvested. They could not be compared to the early production seasons because they were not harvested in 1995-97 (Table 2) because of the low number of ripe fruit.

Average fruit weight in the ninth production season was not uniformly different among the cultivars compared to the first three production seasons. Five cultivars had larger fruit size than in any of the early seasons and four had fruit size equal or smaller than in the previous seasons (Table 3). The mean fruit weights of 'Rossana' and 'Summit' were among the lowest, along with 'Goldie', at 1.5 g per berry but could not be compared to earlier seasons for lack of data.

Discussion

Field longevity of raspberry cultivars has a direct effect on profitability by delaying high establishment costs for new plantings thus increasing the income per establishment unit cost. It is clear that the ability to produce over many seasons varies greatly as indicated by vigor and yield variations in the 11 cultivars tested. Cane densities were much lower than those reported by Goulart and Demchak (1999) even in the most vigorous plots. However, lower cane density did not translate into reduced yields in 'Caroline', and 'Heritage' as it did in some of the other cultivars ['Prelude', 'Kiwigold', and 'Summit' were not tested by Goulart and Demchak (1999)].

In this trial, substantial yield reduction was observed in most cultivars, possibly attributable to decline caused by the root rot organism *P. fragariae* var. *rubi* that was previously isolated from this site (Wilcox, 1989). Low vigor and low sucker production in many plots and observations of root rot indicate root diseases as a primary culprit of the decline. Other diseases and insect pests probably contributed to reduced vigor and yields, as well. Symptoms consistent with raspberry mosaic virus complex were observed in 'Ruby' and 'Summit'. Several

Table 2. The mean yield for 11 primocane fruiting raspberry cultivars in the first three production seasons and the eighth production season in Geneva, N.Y. The percent difference between the mean yield from the first three seasons and the eighth season is also included. The trial was planted at an initial density of 3588 plants/ha (1452 plants/acre) on flat beds with 3.0 m (10 ft) between row centers. The trial had five 7.6-m (25 ft) replicates and drip irrigation was provided to supplement natural precipitation. Dead plots had no yield and were included in means calculation.

Cultivar	Mean yield ^z (kg·ha ⁻¹) ^y					% Change ^x
	1995	1996	1997	1995-97	2002	
Prelude	3943 ab	2036 c	4047 bc	3342 de	3591 ab	+8 ^{ns}
Caroline	3586 ab	6017 b	4283 bc	4629 c	3649 ab	-21 ^{ns}
Heritage	5330 a	4801 bc	3954 bc	4695 bc	3614 ab	-23 ^{ns}
Kiwigold	5529 a	5923 bc	5744 b	5732 b	4015 a	-30*
Goldie ^w	5427 a	4458 b-d	4313 bc	4733 bc	2901 a-c	-39*
Ruby ^w	4429 ab	4437 b-d	4307 bc	4391 cd	1580 b-d	-64*
Autumn Bliss	3445 ab	7954 a	9205 a	6868 a	2282 a-d	-67**
Anne	2586 b	2026 e	3403 e	2668	918 cd	-69*
Amity	3839 ab	3193 de	5291	4085 cd	749 cd	-82**
Summit	n/a	n/a	n/a	n/a	373 d	n/a
Rossana	n/a	n/a	n/a	n/a	213 d	n/a
LSD _{0.05}	1664.4	1521.9	2129.6	1097.3	2341.9	

^xValues in the same column followed by the same letter are not significantly different at $P \leq 0.05$ according to least significant difference (LSD) test.

^y1 kg·ha⁻¹ = 0.89 lb/acre.

^zPercent change between mean of first three seasons and eighth season.

^w'Graton Gold' and 'Watson' are sold under their trademarked names 'Goldie' and 'Ruby', respectively.

^{ns}, *^{*} Nonsignificant or significant at $P < 0.05$ or 0.01, respectively.

Table 3. The mean fruit weight for 11 primocane fruiting raspberry cultivars in the first three production seasons and the ninth production season in Geneva, N.Y. The trial was planted at an initial density of 3588 plants/ha (1452 plants/acre) on flat beds with 3.0 m (10 ft) between row centers. The trial had five 7.6-m (25 ft) replicates and drip irrigation was provided to supplement natural precipitation.

Cultivar	Mean fruit wt ^z (g) ^y			
	1995	1996	1997	2003
Ruby ^x	1.6 a	1.8 d	2.1 c	3.1 a
Autumn Bliss	1.7 a	2.8 a	2.5 a	2.9 a
Prelude	1.6 a	1.9 cd	1.8 d	2.8 a
Caroline	1.7 a	2.0 c	2.0 c	2.8 a
Anne	1.5 a	2.3 b	2.3 b	2.2 b
Amity	1.7 a	2.0 c	1.7 d	2.0 bc
Heritage	1.7 a	1.4 e	1.4 e	1.8 b-d
Kiwigold	1.7 a	1.5 e	2.1 c	1.6 cd
Goldie ^x	1.6 a	1.4 e	1.4 e	1.5 cd
Summit	n/a	n/a	n/a	1.5 d
Rossana	n/a	n/a	n/a	1.5 d
LSD _{0.05}	0.37	0.17	0.12	0.47

^xValues in the same column followed by the same letter are not significantly different at $P \leq 0.05$ according to least significant difference (LSD) test.

^y1.0 g = 0.035 oz.

^z'Watson' and 'Graton Gold' are sold under their trademarked names 'Ruby' and 'Goldie', respectively.

viruses contribute to the mosaic virus complex including the Rubus yellow net, black raspberry necrosis, raspberry leaf mottle and raspberry leaf spot viruses (Funt et al., 1997). Raspberry crown borers (*Pennisetia marginata*) and red necked cane borers (*Agrilus*

ruficollis), which can contribute to stand decline (Funt et al., 1997), were also observed in the field.

Weather can also influence yields, especially in late season cultivars such as 'Heritage', 'Kiwigold', 'Goldie', 'Ruby', and 'Rossana'. Early freeze events can damage fruit at the end of the season making it unmarketable and reducing overall yield. In this trial, an early freeze event occurred on 4 Oct. 1996, which truncated the harvest by 10–14 d compared to 1995, 1997, and 2002. However, yield losses were minimal compared to other seasons (Table 2). In the remaining years, harvest was complete at least 6 d prior to the first freeze event of the season so yield was not affected except in 'Rossana', which was too late for this region.

Fruit weight was consistent across seasons for most of the cultivars (Table 3). Fruit weight was the lowest on average in 1995 [1.6 g (0.06 oz)], which is consistent with a young planting. Rainfall from May through October had no effect on fruit size during the trial. The wettest season was 1996 and overall fruit weight [1.9 g (0.07 oz)] was not different from the driest year, 1997 (1.9 g) and an intermediate year, 2003 [2.0 g (0.07 oz)] [weather data from New York State Agricultural Experiment Station, Cornell University (2004)]. This indicates that fruit size can be maintained over time through adequate irrigation.

'Heritage' has been the standard primocane fruiting cultivar worldwide for more than 20 years with good reason (Daubeney et al., 1992). After eight harvest seasons, vigor was moderate to good and yield showed only moderate decline compared to earlier seasons. The newer cultivar Prelude, released in 1998 (Weber et al., 2004), exhibited higher vigor ratings and a small increase in yield, which indicates greater disease resistance than other cultivars. It has good potential for growers as a primocane or florican fruiting cultivar or in double cropping

systems. The yield of 'Kiwigold' and 'Caroline' in the eighth season was also commercially adequate. However, although 'Kiwigold' had moderate vigor (5.6), it did have substantially lower yields compared to its previous seasons. 'Caroline' had only modest vigor (4.6) in 2002 but had high fruit load and large fruit in healthy plots, which compensated for lost yields in low vigor plots. Even with one dead plot in a wetter section of the field, the yield of 'Caroline' in 2002 was equal to or higher than all of the other cultivars. In a superior field site or with raised beds, 'Caroline' has very good potential for field longevity but may lose vigor in less desirable sites.

Visual vigor ratings and cane density were a good indicator of yield potential but were not always accurate. 'Rossana' had the highest cane density and third highest vigor rating but had the lowest yield. This cultivar produced flowers and fruit too late in the season to ripen before frost and was not suited for New York. 'Rossana' has potential in areas with a longer season or in protected production systems such as high tunnels.

Diversification is increasingly important for enabling small farmers to compete in the marketplace. Primocane fruiting cultivars make raspberries more attractive by providing flexibility to growers in scheduling crop seasons and management programs. Additionally, red raspberry is a crop with a high cash value and great popularity with consumers. However, establishment costs can be high and increasing the longevity of fields directly affects the profitability by reducing inputs over the long term. The cultivars with the most potential to have long production lives in the field are 'Prelude', 'Caroline', 'Heritage' and its sports, 'Kiwigold' and 'Goldie'. They maintained vigor, yield, and fruit size over time and generally produced commercially acceptable yields in the eighth production season.

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