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Performance of Primocane-fruiting Raspberries Grown in the Greenhouse

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Abstract

Seven cultivars of primocane-fruiting raspberries (*Rubus idaeus* L.) were grown for three years in a greenhouse in Simcoe, Ontario. Red raspberry cultivars 'Autumn Bliss,' 'Autumn Britten,' 'Caroline,' 'Heritage,' 'Polana,' and 'Summit,' and the yellow raspberry, 'Anne,' were compared for berry yield, fruit quality, and earliness and consistency of fruiting. Two types of propagules of 'Autumn Britten' were used, tissue-cultured and vegetative, and these behaved similarly with the exception of fruiting consistency in the first harvest season. 'Polana' yielded the most, 'Autumn Britten' produced the largest berries, and 'Summit' and 'Heritage' ranked highest for total fruit quality. Early and consistent fruiting patterns were exhibited by 'Polana,' 'Autumn Britten' and 'Summit.'

Introduction

Greenhouses have been used to produce crops such as tomatoes and cucumbers in the off-season for many years. Recently, off-season production of raspberries has been commercially developed in northern Europe (3) and may have potential in northern North America due to the limited growing season and short post-harvest life of raspberries.

Summer bearing and primocane fruiting raspberry cultivars can be grown in greenhouses where primocane fruiting canes can produce at least two crops in a twelve-month period (2). Primocane fruiting raspberries generally fruit on the tip of the primocane in late summer and fall, while the basal portion bears a summer crop the following year (5). All primocane fruiting raspberries will produce fruit on new primocanes without chilling of the initial root buds (5). Some cultivars, such as 'Summit,' fruit readily without vernalization while with others, such as 'Heritage,' fruiting is delayed (5, 6).

This study evaluates the performance of seven primocane fruiting raspberry cultivars in the greenhouse over a three-year

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period from May 1997 to December 1999 and assesses trends in fruit production in the presence and absence of vernalization.

Materails and Methods

Seven primocane-fruiting raspberry cultivars were used: Anne, Autumn Bliss, Autumn Britten, Caroline, Heritage, Polana, and Summit. Two types of 'Autumn Britten' plants, tissue-cultured and vegetatively-propagated, were included. The majority of the plants were purchased from Strawberry Tyme Farms Inc. in Simcoe, Ontario. Plants of 'Anne' and 'Caroline' were grown from root cuttings of year-old field-grown plants originally bought in 1996 as nursery-matured plants. Tissue-cultured plants of 'Autumn Britten' and 'Polana' and nursery-matured plants of 'Heritage' and 'Summit' were bought in the spring of 1997. 'Autumn Bliss' and vegetative 'Autumn Britten' plants were propagated in the spring of 1997 from root buds of virus-tested mother plants grown at the Horticultural Research Institute of Ontario, Vineland Station, Ontario.

Raspberry plants were potted in 1 gallon Menne grow bags (Menne Nursery Corporation, North Tonawanda, NY) containing a soil-less mixture of peat, vermiculite, perlite, dolomitic limestone and bentonite clay (Professional Mix VPW30, ASB Greenworld Ltd., Mt. Elgin, ON, Canada). Pots were placed in the greenhouse and trellised in May 1997 with cultivars placed in a randomized complete block design with six replicates. Each replicate consisted of eight plots with five to nine adjacent pots of the same cultivar per plot, 1 meter between plots and 1.5 meters between rows.

Greenhouse temperature was maintained above 6 °C at night and above 20 °C during the day. During the summer, a maximum of 39 °C was reached. Plants were grown under ambient day length with the exception of the period between 3 November and 11 December 1997 when lights were on to give a 12-hour photoperiod. Pots were trickle-irrigated to runoff twice daily. Pots were fertilized with 40 grams of 14N-14P-14K, 100 day slow-release fertilizer (Nutricote) after planting in May 1997. Flowers were pollinated by bumble bees, *Bombus impatiens*. A single hive was introduced once flowering started and replaced when the bee population dropped. Occasionally, bees were absent from the greenhouse for up to two weeks. Predominant pests included spider mites and thrips. Spider mites were controlled on a regular basis with *Phytosieulus persimilis*. Thrips were controlled as necessary with *Amblyseius cucumeris*. Canes were pruned back four nodes below the last flowering lateral after fruiting had ceased to allow the development of additional flowering laterals.

All cultivars were affected by poor fruit set for two weeks due to a sudden drop in bumble bee population. This gave lower yields from approximately 20 October

Table 1. Yield and mean berry weight for six primocane-fruiting raspberry cultivars planted in May 1997 and vernalized in 1998.

	Mean berry wt (g)			Marketable yield (g/pot)			Total yield (g/pot)		
Cultivar	1997[z]	1998[y]	1999[x]	1997	1998	1999	1997	1998	1999
Polana	2.9	2.2	2.1	568	654	703	588	698	806
Summit	2.5	2.1	2.0	431	372	745	495	428	907
Autumn Britten[w]	4.0	3.0	3.1	328	571	443	350	635	523
Anne	3.8	3.4	2.7	425	330	574	443	345	609
Caroline	2.5	2.6	2.5	153	605	500	162	646	555
Heritage	2.5	2.0	2.1	258	523	335	280	561	363
LSD 5%	0.2	0.3	0.2	65	140	167	67	148	172

[z]In 1997, raspberries were harvested from 28 July to 12 December 1997 (20 weeks).
[y]In 1998, raspberries were harvested from 10 August 1998 to 1 April 1999 (34 weeks).
[x]In 1999, raspberries were harvested from 5 April to 9 December 1999 (36 weeks).
[w]Data are shown for vegetatively-propagated 'Autumn Britten.'

Table 2. Yield and associated data for five primocane-fruiting raspberry cultivars planted in May 1997 and grown in the greenhouse without vernalization until December 1999.[z]

Cultivar	Mean berry weight (g)		Marketable yield (grams/pot)		Total yield (grams/pot)	
	1998[y]	1999[x]	1998	1999	1998	1999
Summit	2.2	2.0	762	857	864	1083
Polana	2.3	2.2	800	837	853	988
Anne	2.9	2.5	416	704	434	740
Autumn Britten[w]	3.3	2.9	476	531	564	636
Caroline	2.7	2.6	359	445	381	493
LSD 5%	0.35	0.18	195	124	213	137

[z]Plants were cut to the ground in December 1997.
[y]In 1998, raspberries were harvested from 11 May 1998 to 1 April 1999 (47 weeks).
[x]In 1999, raspberries were harvested from 5 April to 9 December 1999 (36 weeks).
[w]Data are shown for vegetatively propagated 'Autumn Britten.'

until 3 November 1997. Fruit was harvested, graded and weighed twice weekly from July until December 1997 when the canes were cut down to the ground. Yields were measured on an individual plant basis. On this date 'Autumn Bliss' was excluded from further trials due to its poor fruit quality.

Once the canes had been cut down to the ground the pots were divided into two sets. One set remained in the greenhouse to study the effects of no vernalization and the other was cold stored at 3 °C. For the non-vernalization experiment, cultivars were set up in a randomized complete block design with six replicates. Each replicate consisted of seven single plant plots placed 0.3 meters apart. Plants were fertilized with 40 grams of 14N-14P-14K, 100 day slow-release fertilizer (Nutricote) on 20 January and 3 March 1998, and then fertilized with 50 grams of 13N-13P-13K slow release fertilizer with micronutrients (Nutricote Plus) on 1 December 1998. 'Heritage' plants were removed 27 March 1998 since no dormant shoots had started growing. All other conditions remained the same as in 1997 except that no additional light was given. Harvesting started on 11 May and continued twice weekly until 9 December 1999.

Vernalized plants were moved outside on 8 May 1998 into a randomized complete block design with six replicates. A replicate consisted of six plots with each plot containing two adjacent pots of one cultivar. Plants were fertilized with 40 grams of 14N-14P-14K, 100 day slow-re-

Table 3. Fruit quality characteristics of six fall-fruiting raspberry cultivars in 1997 and 1998.[z,y]

Cultivar	Color	Brightness	Firmness	Meatiness	Cohesion	Regularity	Skin Strength	Neck	Attractiveness	Total 1997	Total 1998
Summit	3.2	3.5	4.0	4.4	3.4	3.8	3.8	3.2	3.0	32.2	33.0
Caroline	2.9	3.2	3.4	3.4	3.5	3.8	3.8	2.8	3.9	32.0	29.0
Heritage	2.8	2.9	4.2	3.4	3.8	4.2	4.4	3.8	3.4	31.7	34.0
Anne	2.9	3.0	2.8	3.4	3.8	4.4	3.0	3.8	3.2	29.2	31.0
Polana	3.2	3.8	3.1	3.0	3.6	2.6	3.4	3.2	3.3	28.7	29.7
Autumn Britten	3.0	2.5	2.6	2.2	3.6	3.9	2.4	3.2	3.8	27.2	27.2
LSD 5%										2.3	2.2

[z]Plants were vernalized for six weeks in the winter of 1997/1998.
[y]The values for the individual quality characteristics are the means of the 1997 and 1998 harvest data. Data was assessed on a scale of 1 to 5 where 1 = poor and 5 = excellent. Color data was ranked from dark (= 1) to light (= 5).

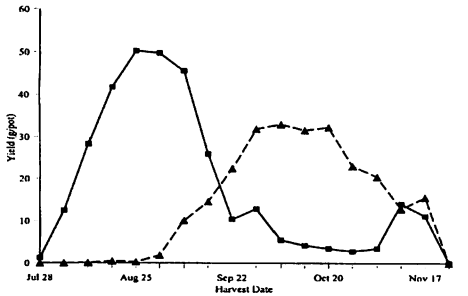

Figure 1. Mean weekly yield of cultivars 'Autumn Britten' (vegetative) and 'Heritage' from canes that had been planted in May 1997. Raspberries were harvested from July 28 to December 13, 1997. 'Autumn Britten' is illustrated by a solid line with ■ markers and 'Heritage' by a dotted line with ▲ markers.

lease fertilizer (Nutricote) on 9 June 1998 and irrigated twice daily by hand. On 19 August 1998, pots were set up in the greenhouse in a similar randomized complete block design with 0.6 meters between plots and one row per replicate. Thereafter, all experimental conditions were the same as for the non-vernalized plants with trickle irrigation, ambient light, and fertilization with 50 grams 13N-13P-13K slow release fertilizer with micronutrients (Nutricote Plus) in December 1998. Harvesting started on 10 August 1998 and continued twice weekly until 9 December 1999.

At each harvest the total fruit weight, number of marketable fruit and the weight of unmarketable fruit was recorded for each plot. On six dates between 17 September and 3 October 1997 and eight dates between 31 August and 28 September 1998 fruit quality was assessed on a scale of one (poor) to five (excellent) for color, brightness, firmness, meatiness, cohesion, regularity, skin strength, neck, overall attractiveness, and flavor. Color data was ranked from dark (= 1) to light (= 5). Flavor data was subjective and was therefore excluded from the total quality rating. Fruiting consistency for each cultivar was estimated by the number of weeks each plant produced an average of two or more berries. This number was considered by us to be large enough to be harvested commercially.

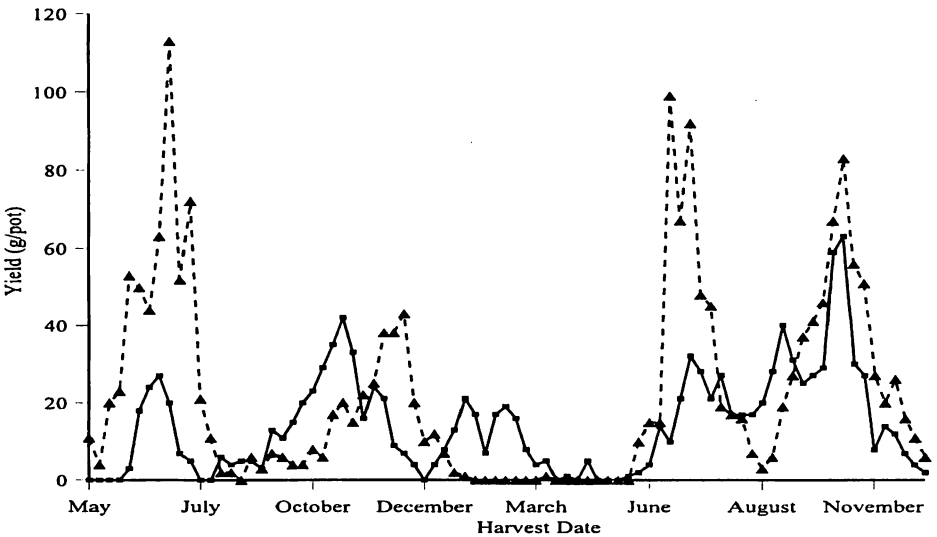

Figure 2. Mean weekly yield of cultivars 'Autumn Britten' (vegetative) and 'Heritage' from canes that had been cut down in December 1997 and cold stored until May 1998. Raspberries were harvested from May 11, 1998 to December 9, 1999. 'Autumn Britten' is illustrated by a solid line with ■ markers and 'Heritage' by a dotted line with ▲ markers.

Table 4. The date of five percent fruit harvest and the percentage of harvest weeks where the mean number of berries per plant was greater than or equal to two for raspberry canes that were vernalized in 1998.

Cultivar	Date of Five Percent Harvest			Percentage of Weeks		
	1997[z]	1998[y]	1999[x]	1997	1998	1999
Polana	26 Aug.	29 Aug.	13 May	75	52	50
Autumn Britten[w]	9 Aug.	2 Sept.	5 June	55	58	78
Summit	25 Aug.	16 Sept.	14 June	80	43	65
Caroline	24 Aug.	17 Sept.	19 July	50	43	52
Anne	26 Aug.	19 Sept.	12 July	70	34	54
Heritage	8 Sept.	22 Sept.	1 Aug.	60	31	42
LSD 5%	9 days	12 days	34 days	n/a	4	4

[z]In 1997, raspberries were harvested from 28 July to 12 December 1997 (20 weeks).
[y]In 1998, raspberries were harvested from 10 August 1998 to 1 April 1999 (34 weeks).
[x]In 1999, raspberries were harvested from 5 April to 9 December 1999 (36 weeks).
[w]Data are shown for vegetatively-propagated 'Autumn Britten.'

Qualitative and quantitative data for each year was analyzed and least significant differences calculated by the GLM procedure of SAS version 6.12 (SAS Institute Inc., 1996). The fruiting period of the primocane-fruiting raspberries did not necessarily correspond to the calender year. In 1997, the first fruiting period started in July and ended in December. In 1998, the second fruiting period commenced in May for non-vernalized canes and in August for vernalized canes and both continued until 1 April 1999. The final period started 5 April, when new canes started fruiting, and continued until 9 December 1999. Mean weekly harvest data was compiled using the MEANS procedure of SAS (SAS Institute Inc., 1996).

Results

Irrespective of vernalization, 'Polana' had high yields (Tables 1 and 2). 'Autumn Britten' had the highest average berry weight with 'Anne' being only slightly smaller. 'Heritage' and 'Summit' had the smallest berries. 'Summit' and 'Heritage' had the highest total fruit quality ratings (Table 3). Relative to the other cultivars tested, 'Autumn Bliss' was crumbly and had poor total fruit quality during the first harvest season (Cohesion = 1.0, Total = 23.0) and was therefore excluded from future greenhouse trials. The two types of 'Autumn Britten,' tissue-cultured and vegetative, did not differ in yield, berry weight or fruit quality in any year (data not shown). Tissue-cultured 'Autumn Britten' produced an average of two or more fruit for 80 percent of harvests (data not shown) compared with vegetative 'Autumn Britten' with 55 percent (Table 4).

The mean weekly yields of vegetative 'Autumn Britten' and 'Heritage' in 1997 showed two extremes of fruiting (Figure

Table 5. The date of five percent fruit harvest and the percentage of harvest weeks where the mean number of berries per plant was greater than or equal to two for raspberry canes that were grown in the greenhouse without vernalization until December 1999.[z]

Cultivar	Date of Five Percent Harvest		Percentage of Weeks	
	1998[y]	1999[x]	1998	1999
Summit	5 June	4 June	45	62
Polana	9 June	12 June	42	57
Autumn Britten[w]	19 July	11 June	42	56
Caroline	13 July	29 July	32	42
Anne	31 July	13 July	38	48
LSD 5%	41 days	30 days	6	4

[z]Plants were cut to the ground in December 1997.
[y]In 1998, raspberries were harvested from 11 May 1998 to 1 April 1999 (47 weeks).
[x]In 1999, raspberries were harvested from 5 April to 9 December 1999 (36 weeks).
[w]Data are shown for vegetatively-propagated 'Autumn Britten.'

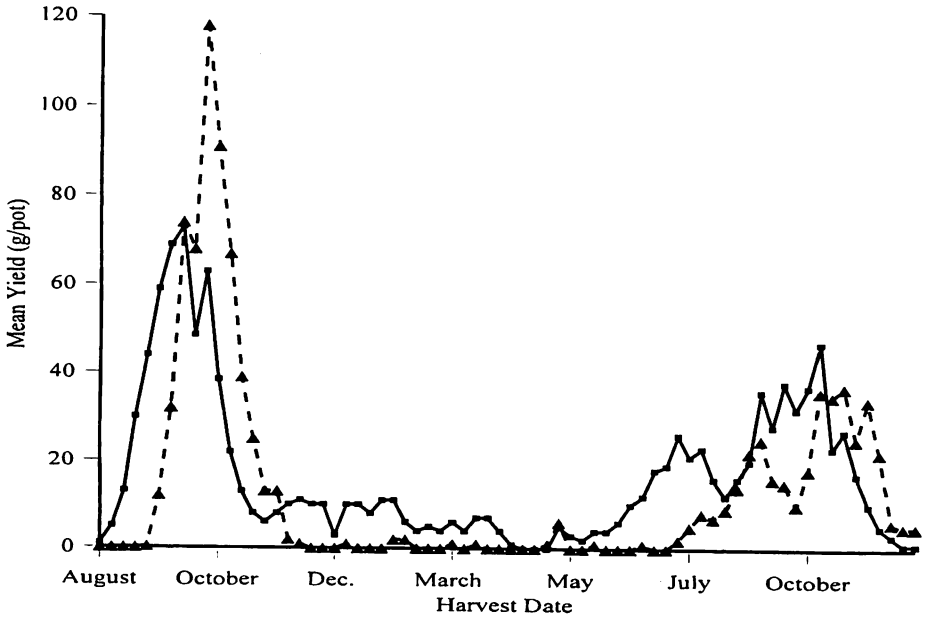

Figure 3. Mean weekly yield of cultivars 'Autumn Britten' (vegetative) and 'Polana' from canes that had been cut down in December of 1997 and kept in the greenhouse. Raspberries were harvested from August 10, 1998 to December 9, 1999. 'Autumn Britten' is illustrated by a solid line with ■ markers and 'Polana' by a dotted line with ▲ markers.

1). 'Autumn Britten' started fruiting early, in late July to early August (Table 4). 'Anne,' 'Caroline,' 'Polana' and 'Summit' fruited in mid-August (Table 4). Conversely, 'Heritage' did not fruit until late August to early September (Table 4). Individual plants of all cultivars produced an average of two or more fruit a week for nine to sixteen weeks although weekly fruit quantity varied with each cultivar.

After vernalization in the winter of 1997 to 1998, 'Autumn Britten' again started fruiting earlier than 'Heritage' (Figure 2). The initial fruiting peaks of each cultivar were larger than their secondary fruiting peaks. 'Polana' and 'Autumn Britten' commenced fruiting in late August while 'Heritage,' 'Caroline,' 'Anne' and 'Summit' started in mid September (Table 4). 'Polana' and 'Autumn Britten' also fruited for the longest duration. After no additional vernalization, 'Polana,' 'Autumn Britten' and 'Summit' resumed fruiting in May to June of 1999 while 'Anne,' 'Caroline' and 'Heritage' started in July to August (Table 4). 'Autumn Britten' fruited for the longest duration in 1999.

Without vernalization in the winter of 1997/1998, 'Polana' and 'Summit' had the highest yields (Table 2) and along with 'Autumn Britten' fruited for the longest duration (Table 5). Each year 'Autumn Britten' had the largest mean berry weight while 'Summit' and 'Polana' had the smallest (Table 2). Yield data for 'Autumn Britten' did not vary with the propagule type so only data for the vegetative type are presented (data not shown).

With a continual lack of vernalization, the mean weekly fruiting yields for 'Autumn Britten' and 'Polana' for 1998 to 1999 exhibited different fruiting patterns (Figure 3). 'Polana' produced two peak yields per year with the summer peak being higher than fall one. 'Autumn Britten' produced three peaks per year with the fall peaks being higher than the summer one. In the absence of vernalization in

1997/1998, 'Polana' started fruiting in early June while 'Autumn Britten' fruited in late July (Table 5). 'Summit' also fruited in June while 'Caroline' and 'Anne' fruited in July. Under these conditions, 'Caroline' fruited for a shorter period than the other cultivars. After a continued absence of vernalization, 'Summit,' 'Polana,' and 'Autumn Britten' resumed fruiting in May to June of 1999 while 'Anne' and 'Caroline' started in July of 1999 (Table 5). By 1999, there were more significant differences in fruiting durations as 'Summit' fruited for the longest period followed closely by 'Polana' and 'Autumn Britten' (Table 5).

Discussion

For greenhouse production of primocane-fruiting raspberries, we consider that the most important characteristic is earliness of fruit because it increases the harvesting period. This is crucial due to the high capital and energy costs associated with greenhouses, and their limited availability for raspberries. 'Autumn Britten' and 'Polana' are both acceptable for greenhouse production as they fruited earliest of the cultivars tested. 'Polana' has greater yields but smaller berries than 'Autumn Britten.' These cultivar characteristics expressed in the greenhouse are similar to those exhibited in field trials (1, 4).

In the greenhouse, 'Summit' produced very high yields and fruited early in the absence of vernalization compared to its performance when vernalized. This trait which was evident here and has been illustrated in other research (5, 6) may make it possible to breed for extremely high yielding cultivars in the absence of vernalization.

This research indicates that primocane-fruiting raspberries have the potential to produce fruit in greenhouses throughout the year. Preliminary analyses indicate that greenhouse raspberry production has economic potential. Fox (1999) analysed one primocane-fruiting system where potted plants were grown in the greenhouse from mid-September to mid-February, cold stored until mid-April, and grown outside from then until mid-September. He concluded that the feasibility of the greenhouse raspberry industry in Ontario is dependent upon yields and prices.

Therefore, economic potential is dependent on the type of production system used. The non-vernalized primocane-fruiting plants used here produced few fruit from January through May. This system is not cost effective as fruit production is low between January and May when both energy costs and raspberry prices are high. A potentially viable production system is one that schedules a minimal vernalization period for primocane-fruiting raspberries so that they produce fruit from mid-February onwards.

Acknowledgments

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