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# Performance of Primocane Fruiting Red Raspberries

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## Abstract

Nine relatively new primocane fruiting raspberry genotypes were evaluated along with 4 standard cultivars in a randomized complete block experiment in central Pennsylvania from 1994-1997. 'Autumn Bliss' and 'Redwing' were the heaviest producers, followed by 'Polana' and 'Caroline.' Heavy yields were primarily a function of earliness, rather than cane density, though cane density varied considerably among cultivars. 'Polana' was a particularly attractive fruit, with a bright red color, even small drupelets, and an ovoid shape. 'Dinkum' also had exceptionally high quality fruit, with good flavor and firmness, however the season was later, resulting in lower yields. The flavor of 'Anne,' 'Caroline' and 'Rossana' were ranked highest. Berry size was largest on 'Ruby' and 'Anne' (two of the lower yielding cultivars), 'Autumn Bliss' and 'Autumn Britten' (two of the highest yielding cultivars). Size and flavor of 'Golden Harvest' was unacceptable for commercial production in this experiment.

## Introduction

In recent years, many cultivars of various small fruit crops have been imported directly by nurseries into North America. Due to lack of funding, these cultivars are often made available to producers with very little or no domestic testing. This has been the case with primocane fruiting raspberries. Therefore, in May of 1994, a primocane fruiting raspberry cultivar evaluation planting was established in central Pennsylvania at the Russell E. Larson Agricultural Research Center in Rock Springs.

The objective of the planting was to evaluate recently available, but relatively untested primocane fruiting raspberries at a fairly cold and late season site. New cultivars included 'Autumn Bliss,' 'Autumn Britten,' 'Dinkum,' 'Golden Harvest,' 'Goldie,' 'Caroline' (formerly JCRF1), 'Anne' (formerly JEFB1), 'Polana' and 'Rossana.' 'Amity,' 'Heritage,' 'Redwing' and 'Ruby' were included in the study as standards.

## Materials and methods

All cultivars were established in May of 1994 except for 'Polana,' 'Autumn Britten' and 'Dinkum,' which were planted into reserved spaces in the experimental design in May of 1995 when plants became available. Meristem-tip cultured plants were used for all cultivars except 'Ruby' and 'Redwing,' which were dormant canes. All plants were obtained from commercial nurseries in the United States. In both years, plants were spaced at 2 feet between plants and 10 feet between rows, allowing 12 feet between plots to keep cultivars from co-mingling. Trickle irrigation was installed, and plants were mulched with 4 inches of clean straw mulch to aid in establishment (7). Irrigation was applied as needed, with at least 2" per week applied during harvest when conditions were dry. Pests were monitored for and controlled as recommended (4).

Plants were arranged in a randomized complete block design with 4 replications. Data was collected from the center 2 meters of each plot only. Data was analyzed using analysis of variance, and means were separated using Tukey's Mean Separation technique.

Flower and fruit stage of development were assessed once a week during the 1995 growing season on at least 3 of the four replications. Primocane density was determined by counting the number of emerged primocanes in a representative 0.5 $m^2$ area of each plot during the fall

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after the plants had defoliated. Yield data was collected three times weekly for the summer crop (1995 only), and twice weekly for the fall crop in all years (1995-1997).

Taste data was collected on 24 September 1997 by asking evaluators (Penn State faculty and staff) to give each cultivar a taste rating from 1 to 5. Five berries at optimal ripeness were selected from each plot on the same date, and % brix was determined in a composite juice sample for each plot using a hand refractometer (Atago N1, Japan). Japanese beetle infestation was rated on a scale of 1-5, where 1 = no beetles present and 5 = high numbers of beetles present. Leaf hopper susceptibility was rated on a scale of 1-5, where 1 = no chlorosis and leaf curling from infestation, and 5 = severe chlorosis and leaf curling from infestation.

Weather conditions varied from year to year. The 1995 growing season was comparatively dry, 1996 was wet, and 1997 was cool all season and drier than usual through July (Table 1) .

## Results and Discussion

*Vegetative Characteristics*

Primocane density is an important factor in evaluating primocane fruiting cultivars, since it's a parameter that has been shown to be directly related to yield in some primocane fruiting cultivars (6). Primocane density for 1997 varied among cultivars, with 'Caroline' and 'Heritage' having the highest primocane density, and 'Anne' having the lowest (Table 2).

When comparing primocane density over the last 2 years of the study, most cultivars showed an increase in primocanes (Figure 1). The exceptions to this rule were 'Ruby' and 'Anne.' 'Ruby' appeared to be infected with crown gall, which may have originated at the nursery, since the site was not planted to a crown gall susceptible crop prior to planting the raspberries, and all the replicates showed gall symptoms. The galls may have affected primocane production. 'Redwing' also showed crown gall, though to a much lesser extent. Canes of this cultivar also tended to be larger in diameter, suggestive of the growth habit of one of its parents, 'Titan,' which is also highly susceptible to crown gall.

There were differences in primocane height in the fall, with 'Amity,' 'Polana' and 'Caroline' being the shortest of the cultivars, and 'Anne,' 'Ruby,' 'Rossana,' 'Heritage,' 'Dinkum' and 'Redwing' being the tallest (Table 2). Node numbers tended to follow the same trend as height. There were fewer distinctions in cane diameter, though 'Amity' had a smaller diameter than many of the cultivars, and 'Anne' had a larger diameter than many. The percentage of canes within 15 cm of the crown in the first year was highest for 'Anne' (indicating a tendency to produce canes from or close to the original plant crown), and lowest for 'Amity,' 'Caroline,' 'Goldie,' 'Ruby,' 'Rossana' and 'Heritage,' indicating that these cultivars sucker more readily from the roots, and more quickly establish a uniform stand of canes (data not shown). It should also be noted that by 1997, there were no differences among cultivars in this parameter, suggesting that the characteristic is ephemeral among primocane fruiting cultivars of raspberries.

When cultivars were ranked for Japanese Beetle infestation, it was found that there were no differences among cultivars (data not shown). However, there were differences among cultivars in injury sustained due to an infestation of leafhoppers. Specifically, 'Amity,' 'Rossana' and 'Dinkum' had more chlorosis and leaf curling than 'Autumn Bliss,' 'Redwing' or 'Golden Harvest,' with all other cultivars intermediate in response (data not shown).

*Reproductive characteristics*

'Autumn Bliss' was among the earliest cultivars to flower for both the summer and the fall crop, and had the first ripe fruit for the summer crop (Table 3). For the fall crop, both 'Amity' and 'Autumn Bliss' had first ripe fruit on 17 August 1995.

In 1996/97, 'Autumn Bliss' and 'Polana' were the first cultivars to yield substantial harvests (Table 4). 'Autumn

Bliss,' 'Redwing,' 'Caroline' and 'Polana' all yielded more marketable fruit than 'Anne,' 'Goldie,' 'Ruby,' 'Heritage,' 'Dinkum' and 'Autumn Britten,' with 'Golden Harvest' and 'Amity' intermediate in marketable yield. Total yield reflected this trend as well. Yield remaining tended to be inversely related to yield harvested, with 'Autumn Bliss' having only 35% of fruit not harvested due to a fall freeze, while cultivars such as 'Heritage' and 'Ruby' still had 82 and 81% of their fruit unharvested at the time of the freeze. However, lower yields were not solely due to lateness of harvest, since cultivars such as 'Anne' also had very low primocane densities.

Cumulative yield over time was fairly consistent in 1996 and 1997, though in 1995, 'Redwing' yielded much higher than any other cultivar, even though it started producing fruit later in the season (Figure 2). Consistent over the years, however, were the lowest yield occurring on 'Anne,' 'Goldie,' 'Ruby' and 'Heritage' and the highest yield occurring on 'Autumn Bliss,' 'Redwing,' and 'Caroline.' 'Polana' was also a remarkable producer, particularly considering that it was planted a year later than the other cultivars with high yield.

Berry size was largest on 'Ruby' and 'Anne,' two of the lower yielding cultivars, and smallest for 'Goldie,' 'Golden Harvest,' 'Amity,' 'Redwing' and 'Heritage' (Table 4). 'Autumn Bliss,' which was extremely high yielding, had very acceptably sized fruit at a season average of 2.9g. 'Polana' fruit was intermediate in size, but is noteworthy because of the extreme beauty (even drupelets, shiny surface, slightly ovoid shape and bright color) of the fruit.

Flavor, a difficult parameter to interpret, was ranked highest for 'Anne' and 'Caroline,' and lowest for 'Golden Harvest,' consistent with the authors' perceptions. These rankings, particularly those on the lower end of the scale, were not necessarily related to soluble solids, however 'Anne' did have the highest soluble solids.

It should be noted that the flavor of 'Rossana' was outstanding, even though it had virtually no other positive attribute, being susceptible to insect and disease attack, and was too late in bearing fruit to be useful for our climate. Because of this latter problem, 'Rossana' was not included in the yield analysis.

*Genetic background of new cultivars and authors' comments:*

'Amity' is a short plant with moderate cane densities. Productivity is intermediate, as is earliness of fruiting. The flavor and fruit size is mediocre, and the fruit is difficult to remove from the receptacle when ripe in some years.

'Anne' (formerly JEFB1) is a cross between 'Amity' and 'Glen Garry' which was made in 1989 by Dr. Harry Swartz, University of Maryland. It was purported to be considerably earlier than 'Heritage' with larger fruit, medium vigor and low suckering. Release is planned for 1999. (unpublished data, H. J. Swartz).

'Anne' is a medium to tall plant which produces very few primocanes. Because

**Table 1. Precipitation and temperature conditions in central Pennsylvania for 1995-1996.[z]**

| Year | May | June | July | August | September | October |
|---|---|---|---|---|---|---|
| | | | Temperature (C) | | | |
| 1995 | –1.7 | 0 | 0 | +2.2 | –0.6 | +2.2 |
| 1996 | –1.1 | +1.1 | –1.7 | –0.6 | 0 | 0 |
| 1997 | –2.2 | 0 | –0.6 | –1.7 | –1.1 | 0 |
| | | | Rainfall (cm) | | | |
| 1995 | –0.51 | 0 | –5.1 | –6.9 | –4.6 | +10.2 |
| 1996 | +0.76 | +2.15 | +1.5 | –0.51 | +17.8 | +4.1 |
| 1997 | –0.76 | –3.81 | –5.3 | +5.6 | +1.8 | –5. |

[z]Precipitation and temperature expressed as variation from the 30 year norm.

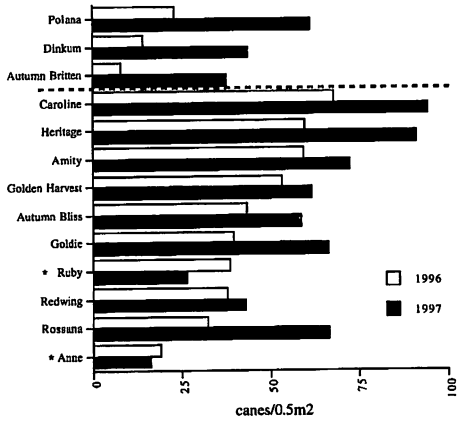



**Figure 1. Cane densities of primocane fruiting cultivars of red raspberries in 1996 and 1997. Cultivars above broken line were planted in 1995, those below in 1994.**

of this, productivity is relatively low. Its season is intermediate. Fruit is a true yellow color, large, slightly rough in appearance, and has a wonderful flavor that has overtones of banana. This flavor improves as the season progresses.

'Autumn Bliss,' also referred to as 'Malling Autumn Bliss,' originated in East Malling, England as a complex cross involving *Rubus strigosus, R. arcticus, R. occidentalis,* as well as the red raspberry cultivars 'Malling Landmark,' 'Malling Promise,' 'Lloyd George,' 'Pyne's Royal,' 'Burnetholm' and 'Norfolk Giant.' Released by E. Keep, J. H. Parker and V. H. Knight, it was introduced in 1984. Fruit is very early, large, with a pleasant rather mild flavor. It was reported to outyield 'Heritage' in England (1).

'Autumn Bliss' is medium to tall in height, with moderate cane densities. Productivity is very high, and it is the earliest fruiting cultivar in our trial. Flavor ranges from good to excellent, fruit are good sized, but are not as shiny or smooth as some of the other cultivars, such as 'Polana' or 'Dinkum.'

'Autumn Britten' originated in East Malling, Kent, U.K. and was released by V. H. Knight, E. Keep and J. H. Parker in 1995. It is a sibling of 'Autumn Bliss,' having its complex genetic background. It is purported to be large, medium to dark red, firm, and often more uniform than 'A. Bliss.' It was also purported to ripen a few days after 'A. Bliss,' with similar yields and growth habit (3).

'Autumn Britten' is a medium height plant with low to medium cane densities. Yield is intermediate as is season. Fruit size and flavor are excellent at the begin-

**Table 2. Vegetative parameters of primocane fruiting raspberry cultivars, 1996-97.[z]**

| Cultivar | Primocane density (#10.5m2)[y] | Height (cm) | Node # | Diameter (mm) | % Canes within 15cm of crown[x] |
|---|---|---|---|---|---|
| 'Amity' | 72.5bc | 877.6a | 27.9ab | 9.5a | 16a |
| 'Polana' | 61.3ac | 882.6ab | 31.5ad | 9.8ac | — |
| 'Caroline' | 94.3c | 970.3ac | 27.0a | 9.7ab | 13a |
| 'Golden Harvest' | 61.8ac | 1047.1bd | 32.0bd | 10.4ac | 29ac |
| 'Autumn Britten' | 37.8ac | 1048.7bd | 32.4bd | 11.9cd | — |
| 'Autumn Bliss' | 58.8ac | 1068.2bd | 29.1ac | 11.8cd | 29ac |
| 'Goldie' | 66.5bc | 1133.5cd | 35.6d | 10.8ac | 19a |
| 'Anne' | 16.0a | 1142.7d | 36.5d | 12.9d | 61d |
| 'Ruby' | 26.5ab | 1153.8d | 34.6d | 11.4bd | 12a |
| 'Rossana' | 66.5bc | 1153.9d | 34.8d | 10.4ac | 16a |
| 'Heritage' | 91.0c | 1163.9d | 35.4d | 10.8ac | 21ab |
| 'Dinkum' | 43.8ac | 1175.8d | 33.6cd | 11.6bd | — |
| 'Redwing' | 43.0ac | 1177.4d | 36.0d | 10.9ac | 39bd |
| p(F) | <0.001 | <0.001 | <0.001 | <0.001 | 0.03 |

[z]Data presented for height, node number and cane diameter was combined for 1996 and 1997 since there were no cultivar*year interactions.
[y]For 1997 only to reflect cane densities of a mature planting.
[x]Used to indicate how densely new canes were concentrated in crown area in the first year of the planting (1995).

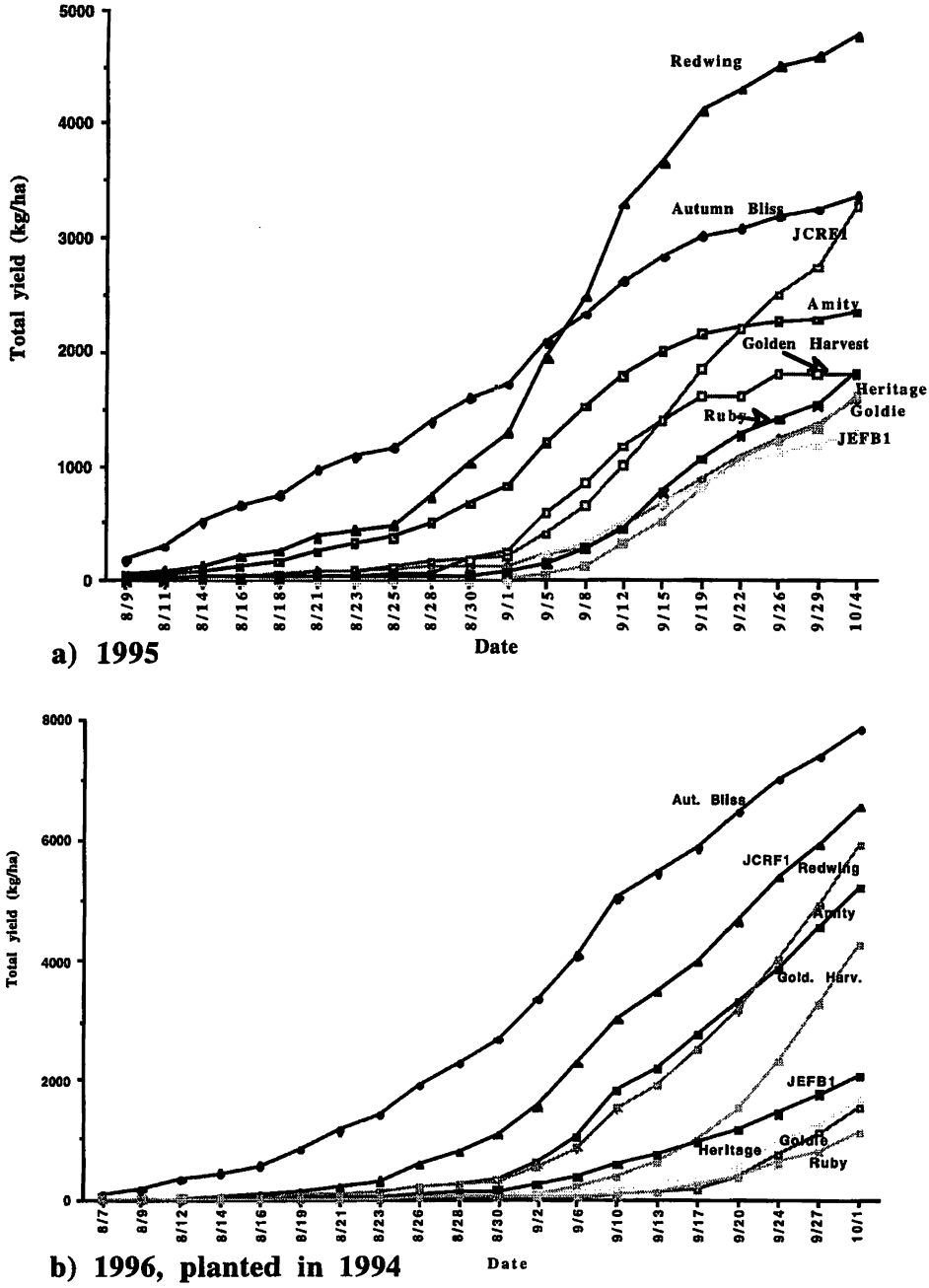
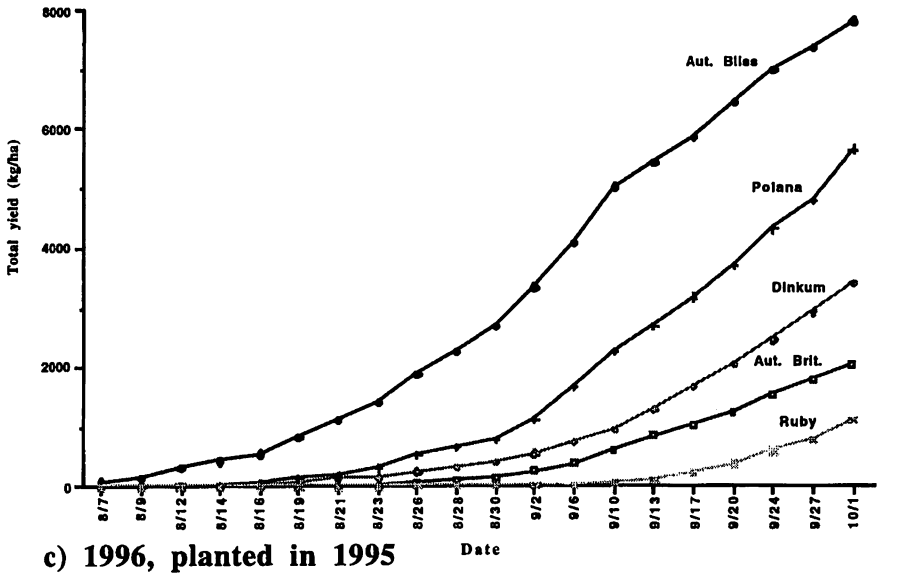
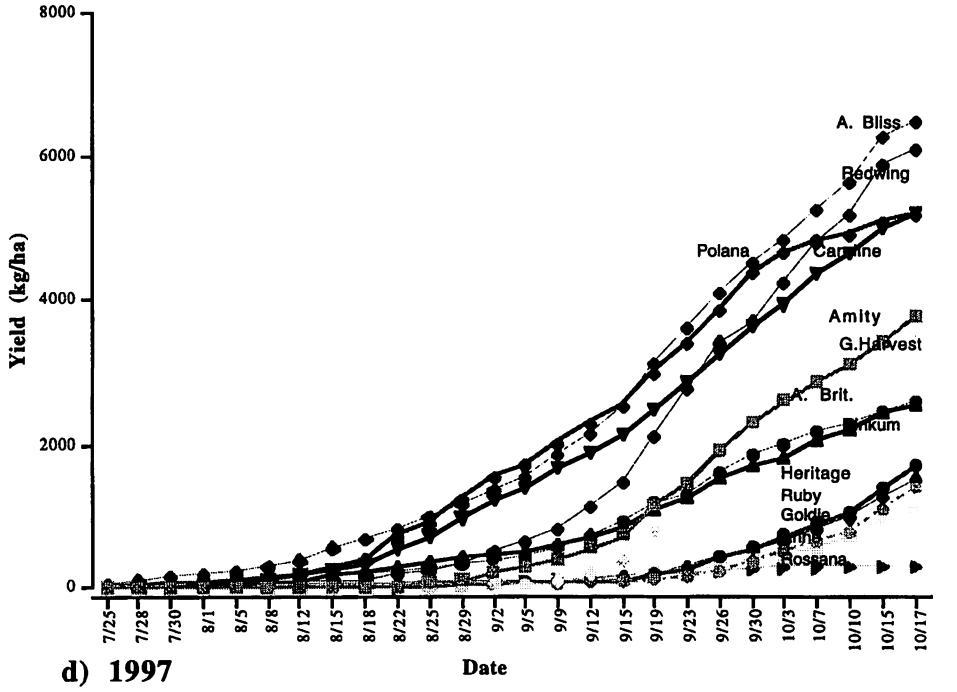



**Figure 2. Cumulative yield of primocane fruiting raspberry cultivars. a) 1995, b) 1996, data for cultivars planted in 1994, c) 1996, data for cultivars planted in 1995, d) 1997.**




c) 1996, planted in 1995




d) 1997

**Figure 2. (Continued).**

**Table 3. Timing of phenological stages of primocane fruiting cultivars, 1995.**

| Cultivar | 1st bloom | 50% bloom | 10% green | 50% green | 1st ripe | % summer[z] |
|---|---|---|---|---|---|---|
| | | | Summer | | | |
| 'Amity' | 7-Jun | 14-Jun | 21-Jun | 12-Jul | 12-Jul | 13 |
| 'Autumn Bliss' | 30-May | 14-Jun | 21-Jun | 28-Jun | 28-Jun | 28 |
| 'Golden Harvest' | 30-May | 14-Jun | 21-Jun | 21-Jun | 5-Jul | 53 |
| 'Goldie' | 7-Jun | 14-Jun | 28-Jun | 5-Jul | 5-Jul | 17 |
| 'Heritage' | 7-Jun | 14-Jun | 28-Jun | 12-Jul | 12-Jul | 10 |
| 'Caroline' | 30-May | 14-Jun | 21-Jun | 28-Jun | 5-Jul | 19 |
| 'Anne' | 7-Jun | 14-Jun | 21-Jun | 28-Jun | 5-Jul | 17 |
| 'Redwing' | 30-May | 14-Jun | 21-Jun | 5-Jul | 5-Jul | 17 |
| 'Rossana' | 7-Jun | 14-Jun | 21-Jun | 5-Jul | 5-Jul | — |
| 'Ruby' | 7-Jun | 14-Jun | 21-Jun | 28-Jun | 5-Jul | 33 |
| | | | Fall | | | |
| 'Amity' | 26-Jul | 2-Aug | 2-Aug | 17-Aug | 17-Aug | — |
| 'Autumn Bliss' | 26-Jul | 2-Aug | 9-Aug | 17-Aug | 17-Aug | — |
| 'Golden Harvest' | 2-Aug | 9-Aug | 17-Aug | 23-Aug | 30-Aug | — |
| 'Goldie' | 2-Aug | 8/2-8/23 | 17-Aug | 30-Aug | 30-Aug | — |
| 'Heritage' | 2-Aug | 23-Aug | 30-Aug | 5-Sep | 5-Sep | — |
| 'Caroline' | 2-Aug | 17-Aug | 17-Aug | 1-Sep | 1-Sep | — |
| 'Anne' | 2-Aug | 17-Aug | 17-Aug | 30-Aug | 5-Sep | — |
| 'Redwing' | 26-Jul | 9-Aug | 9-Aug | 23-Aug | 23-Aug | — |
| 'Rossana' | 17-Aug | — | — | — | — | — |
| 'Ruby' | 2-Aug | 9-Aug | 17-Aug | 30-Aug | 30-Aug | — |

[z]% of the crop which was borne in the summer.

ning of the season, however they tend to diminish as the season progresses.

'Caroline' (formerly JCRF1) is a complex cross (Geo-1 ('Autumn Bliss' X 'Glen Moy') X 'Heritage') which was made in 1989 by Dr. Harry Swartz, University of Maryland. The fruit was purported to have good flavor and good shelf-life, while harvest was 2 weeks earlier than 'Heritage' in New Jersey, with higher yields. Release is planned for 1999 (unpublished data, H. J. Swartz).

While on average, 'Caroline' is a fairly short plant, in fact, it has both very tall and very short canes and very high primocane density. The short canes bear fruit quite early in the season, while the tall canes bear later. Yields are quite high, and the fruit flavor is excellent, with a very raspberry taste, though the flavor seems to diminish as the season progresses. Fruit is a little rough looking.

'Dinkum' is an Australian cultivar which was introduced by G. McGregor, Victoria Department of Agriculture, Toolangi, Victoria, Australia in 1992. It is an 'Autumn Bliss' X 'Glen Moy' cross made in 1983 by D.L. Jennings at the Scottish Crop Research Institute. It was purported to have medium sized firm and glossy fruit, excellent flavor, and to ripen as much as 19 days earlier than 'Heritage.' (2).

'Dinkum' is a tall plant with moderate primocane densities. Productivity is medium to low, and the season is fairly late. The berries are exceptionally beautiful, slightly conic but rounded, with very even drupelets. Flavor and firmness are excellent.

'Golden Harvest' was offered by NorthStar nurseries exclusively. Described as having medium-sized fruit which is firm, little information was available on it, other than that it had displayed no instance of bushy dwarf virus, and was free of crown gall (5).

'Golden Harvest' is a short to medium plant in height which is sprawling and highly branched, an unusual characteristic

**Table 4. Yield and fruit characteristics of primocane fruiting raspberry cultivars, 1996-1997.**

| Cultivar[z] | Date of 1st harvest >100 kg/ha[y] | Marketable Yield (kg/ha) | Total Yield (kg/ha) | Yield rem.[x] (%) | Mean berry mass (g) | Flavor Ranking[v] | Soluble Solids (brix)[y] |
|---|---|---|---|---|---|---|---|
| 'Anne' | 9/30 | 1333.2ef | 1736.3f | 73ac | 3.2ab | 4.3c | 12.8f |
| 'Goldie' | 9/26 | 1272.6ef | 1748.9f | 77ab | 2.1fg | 2.6ac | 11.0ce |
| 'Ruby' | 9/23 | 1085.5f | 1724.8f | 82a | 3.4a | 2.9bc | 10.2ae |
| 'Heritage' | 9/26 | 1496.2ef | 1940.4f | 81a | 2.2ef | 2.8ac | 10.4ae |
| 'Dinkum' | 9/9 | 2747.8de | 3302.3ef | 56bd | 2.6cd | 3.3bc | 10.2ae |
| 'Autumn Britten' | 9/9 | 2035.6ef | 2732.2f | 50d | 2.9bc | 2.9bc | 9.6ac |
| 'Golden Harvest' | 9/12 | 3662.9cd | 4508.4de | 49d | 1.9g | 1.3a | 10.0ad |
| 'Amity' | 9/2 | 4112.8bc | 4903.3ce | 41d | 2.2fg | 3.0bc | 10.9be |
| 'Polana' | 8/15 | 4960.0ac | 5807.2bd | 50d | 2.4df | 2.9bc | 9.5ab |
| 'Caroline' | 8/22 | 5264.9ab | 6304.7ac | 49d | 2.5de | 3.8c | 9.5ab |
| 'Redwing' | 8/29 | 5392.6ab | 6699.6ab | 54cd | 2.1fg | 1.9ab | 11.1de |
| 'Autumn Bliss' | 8/12 | 6402.7a | 7798.4a | 35d | 2.9bc | 3.0bc | 9.0a |
| p(F) | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

[z]Means followed by the same letter are not significantly different.
[y]1997 data only.
[x]Calculated by estimating the percent of fruit which was not harvested as compared to receptacles which had been harvested.
[v]Flavor ranking and soluble solids reported for 1997 only. 1 = dreadful, 5 = best flavor.

in primocane fruiting raspberries. It is intermediate in productivity and season. The fruit is abundant and yellow, however flavor is unacceptable, as is size.

'Goldie' is a sport (a chance mutation) of 'Heritage' which was discovered in Sonoma County, California in 1987. It was purported to have comparable fruit production, berry firmness and overall performance to 'Heritage,' but with a golden fruit (2).

'Goldie' is a medium height plant, with medium to high primocane production. It is relatively unproductive, due largely to lateness of flowering and fruiting in the season. The fruit is medium sized, more of an orange or pink color than gold, good in flavor.

'Heritage' is a medium to tall plant with very high primocane production. Its productivity is relatively low in this trial, due to lateness. The fruit is less affected by light frosts than other cultivars. The fruit is medium sized, attractive, firm and very flavorful.

'Polana' is a Polish cultivar which originated in Brzezna, Poland by Jan Danek and Zofia Pasuit. It is a 'Heritage' X 'Zeva Herbsternte' cross, and was introduced in 1991. Fruit is purported to be medium size and compact, to ripen earlier than 'Heritage,' and be aromatic and tasty but with quality deterioration in the late season. It was only recently made available in North America (2).

'Polana' is a short plant with medium to high primocane densities. Productivity is high, and fruiting is fairly early. The fruit is very attractive and shiny, however it has a split receptacle more often than any other of the cultivars tested, as well as some difficulty with plugging. Flavor is good to mediocre.

'Redwing' is a very tall plant with moderate primocane densities. It has a tendency to lodge. Productivity is very high, though it is later to begin fruiting than 'Autumn Bliss.' Fruit quality is highly variable. At its best, the fruit is 'Heritage'-like, however much of the fruit is small, malformed (few or uneven drupelets) and lacking in flavor.

'Rossana' originated at the University of Tornia, Italy, and was released by R. Paglietti. It is the result of an open pollinated 'Malling Promise' seed. Fruit was purported to be medium in size (though larger than 'Heritage'), and to yield 1 week later than 'Heritage.' It was virtually untested in the North America at the time of planting.

'Rossana' is a medium to tall plant with high primocane densities. Its productivity is nearly non-existent in our climate because it is so late in developing. The few fruit that we were able to harvest had the best flavor of any of our cultivars, though. It has a strong raspberry flavor (some tasters thought too strong).

'Ruby' is a tall plant with fairly low cane densities in our planting. This may have been due to crown gall infections in the plants which appeared in the second year. Productivity is low, and the season fairly late. Fruit is large, but slightly rough looking. Flavor is described by some as very mild, but we feel it is better described as flavorless.

In summary, 'Autumn Bliss' and 'Redwing' were the heaviest producers, followed by 'Caroline' and 'Polana.' Heavy yields were largely a function of earliness. 'Rossana,' 'Anne,' 'Goldie,' 'Ruby' and 'Heritage' yielded little, mostly because they yielded late, with more than 70% of the fruit produced never ripening. 'Anne,' 'Ruby,' 'Autumn Britten' and 'Autumn Bliss' all produced large berries.

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# Growth Characteristics of Selected Pecan Rootstocks Prior to Grafting

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## Abstract

Six pecan (*Carya illinoinensis* (Wangenh.) K. Koch) cultivars and five pecan families (closely related individuals from a native stand, seed from at least 10 native trees were pooled) were evaluated for use as rootstocks. The evaluation period was from seed planting through 4-years-old, but before the rootstocks were grafted. 'Apache' rootstocks grew more rapidly than the other rootstocks tested during the first two years. However, by the fourth year 'Apache' and 'Peruque' trees were similar in height, and trunk diameters of 'Apache,' 'Giles' and 'Peruque' were not significantly different. Coefficients of variation for tree heights and trunk diameters indicated that variability between individuals was similar within most cultivars and families. Budbreak date was strongly influenced by rootstock source, with up to a 14 day difference between the first and last rootstocks to attain 90% budbreak. An April freeze damaged current season's growth on 90% of the 'Apache' trees, but only 10% of the 'Giles,' 'Starking Hardy Giant,' and natives from Chetopa, KS and Sapulpa, OK were injured. Freeze damage was dependent on the bud developmental stage. Several significant differences in leaf elemental concentrations between rootstocks were identified.


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