

Raspberry Variety Performance in Southern Michigan

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SUMMARY. Seven primocane-fruiting and 15 floricanes-fruiting raspberry varieties (*Rubus idaeus*) were compared for three fruiting seasons on a loamy sand soil in southwest Michigan. The earliest primocane-fruiting varieties ('Autumn Bliss', 'Autumn Britten', 'Polana') began ripening 3 weeks before the standard variety, 'Heritage'. 'Autumn Bliss' was the most productive early primocane-fruiting variety. 'Caroline' and 'Dinkum' ripened about 1 week earlier than 'Heritage', and 'Ruby' was 2 days later. 'Caroline' was the most productive of this group and also had large fruit that were somewhat resistant to rot caused by *Botrytis cinerea*. 'Caroline' also received the greatest leaf feeding from rosechafer beetles (*Macroductylus subspinosus*). Most primocane-fruiting varieties were fairly resistant to leaf spot (*Sphaerulina rubi*), while 'Dinkum' was highly susceptible to spur blight (*Didymella applanata*). Floricanes-fruiting varieties were evaluated based on fruit production and quality as well as winter injury to canes, disease resistance, and feeding injury from two-spotted spider mites (*Tetranychus urticae*). The floricanes-fruiting varieties showing minimal winter injury were 'Boyne', 'Killarney', 'Latham', 'Nova', and 'Prelude'. 'Canby', 'Encore', 'Glen Ample', 'Qualicum', 'Reveille', 'Titan', and 'K 81-6' were moderately hardy; while 'Tulameen', 'Malahat', and 'Lauren' were not hardy enough for this location. 'Reveille', 'Killarney', 'Boyne', and 'Prelude' were the most productive floricanes-fruiting varieties. 'Nova' and 'Qualicum' had low levels of botrytis rot. 'Nova' was most resistant to leaf spot and also had resistance to spur blight. Injury from mites was greatest on 'Glen Ample' and lowest on 'Malahat', 'Prelude', 'Qualicum', and 'Tulameen'. 'Caroline' (primocane-fruiting), 'Prelude', and 'Nova' (floricanes-fruiting) were promising newer varieties.

Although Oregon, Washington, and California are the primary red raspberry production areas in the U.S., most states have some commercial acreage. A key to successful production is choosing the varieties best suited to local conditions and markets. Identifying the best varieties is often difficult because performance varies by location. New varieties are regularly released from various breeding programs, but are not adequately tested in most states with small raspberry industries and limited resources. Lack of testing delays adoption of new varieties, and forces some growers to test new genotypes on their farms or choose varieties based on inadequate information.

Michigan has less than 200 ha of raspberries (Kleweno and Mathews, 2002). Both floricanes-fruiting and primocane-fruiting varieties are grown, and most fruit are marketed directly to consumers on the farm or at local farmers' markets. An essential requirement of floricanes-fruiting varieties in Michigan is adequate cane hardiness to withstand winter temperatures, which usually reach -18 to -23 °C in southern areas and below -29 °C farther north. An important characteristic of primocane-fruiting varieties in northern regions is early maturation of fall berries, since harvest usually concludes

with the first fall freeze. The average length of the frost free period ranges from 170 d in southern Michigan to less than 100 d in northern areas. An essential characteristic of all raspberries is flavorful, attractive fruit that retain their quality for several days after picking.

Raspberry plants are likely to be infested by insects, mites, and diseases if grown in Michigan, and resistance to pests may be used to select adapted varieties. The rosechafer beetle and the two-spotted spider mite are two key arthropod pests of raspberry (Ellis et al., 1991). The beetle feeds on leaves and flowers for a few weeks in the spring. Populations of two-spotted spider mites are typically suppressed by various species of predatory mites, and removal of predators by inappropriate use of pesticides can lead to high pest mite populations and plant injury. High levels of feeding by both two-spotted spider mite and rosechafer beetle have the potential to delay fruit ripening and reduce the fruiting potential for the following year. Diseases of raspberries in Michigan tend to be mainly fungal in nature (Wise et al., 2003). Virus diseases have been less of a problem now that certified virus-tested planting material is widely available. Common leaf and cane diseases are leaf spot, anthracnose (*Elsinoe veneta*), spur blight, and cane blight, whereas botrytis gray mold is the predominant fruit rot disease (Ellis et al., 1991). Foliar and cane diseases may reduce plant vigor, productivity and winter hardiness, and botrytis gray mold reduces fruit quality and marketability (Ellis et al., 1991). While growers usually rely on pesticides for insect pest and disease control (Wise et al., 2003), varieties that are less susceptible to pests and diseases may require less chemical intervention. Less pesticide use can encourage greater activity of biological control agents, and reduce production costs and pesticide residues in fruit.

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
2.5400	inch(es)	cm	0.3937
1.1209	lb/acre	kg·ha ⁻¹	0.8922
28.3495	oz	g	0.0353
0.4732	pt	L	2.1134
2.2417	ton/acre	t·ha ⁻¹	0.4461
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

In Michigan the most popular primocane-fruiting varieties are 'Heritage' and 'Autumn Bliss'; whereas 'Canby', 'Latham', and 'Boyne' are standard floricanefruiting types (Kleweno and Mathews, 2002). 'Latham', 'Boyne', and 'Heritage' are also grown widely in other midwestern states (Nonnecke and Luby, 1992). There is significant interest and potential for commercial production of summer and primocane-fruiting raspberries in Michigan. Numerous recently released varieties may offer improvements over traditional choices, and could increase raspberry profitability and acreage in Michigan. The goal of this project was to determine the suitability of newer primocane and floricanefruiting varieties for use in Michigan and other areas with similar climatic conditions.

Materials and methods

Seven primocane-fruiting varieties ('Autumn Bliss', 'Autumn Britten', 'Caroline', 'Dinkum', 'Heritage', 'Polana', and 'Ruby') and 15 floricanefruiting varieties ('Boyne', 'Canby', 'Encore', 'Glen Ample', 'Killarney', 'Nova', 'Latham', 'Lauren', 'Malahat', 'Prelude', 'Qualicum', 'Reveille', 'Titan', 'Tulameen', and 'K81-6') were planted in adjacent trials in 1999 on a loamy sand soil at the Southwest Michigan Research and Extension Center in Benton Harbor. The location was within USDA Hardiness Zone 6a (Cathey, 1990), and had elevation and slope for excellent air flow. Plots were single, 15-ft-long rows, with three replications per treatment arranged in a completely randomized design. One of the three plots of 'Polana' was planted in Apr. 2000 due to inadequate plant numbers. Plant spacing was 3 ft within rows and 10 ft between rows. Irrigation was provided with a trickle system with in-line emitters spaced at 18 inches and delivering 0.5 gal/h. Weeds emerging within the rows were controlled with April applications of oryzalin and simazine, spot spraying with glyphosate, and hand weeding. A 5-ft-wide sod strip was maintained between rows. Annual fertilization consisted of 50–70 kg·ha⁻¹ nitrogen applied in three applications in April, May, and June. Plants were sprayed 2–4 times each year with fungicides (captan, benomyl, or iprodione) and 1–4 times with insecticides (malathion or carbaryl), in an attempt to maintain some disease and insect pest pressure

while preventing severe outbreaks. The primocane-fruiting varieties were pruned to ground level each March. Floricanefruiting varieties were pruned in March by retaining the largest canes (up to 20 per linear meter of row), and by removing floricanes when harvest was completed. A T-trellis supported the plants. Buffer rows were planted on each side of the experimental area and 10-ft lengths of buffer plants were maintained on the ends of all rows.

Varieties were evaluated for three fruiting years (2000–02 for primocane-fruiting types, 2001–03 for floricanefruiting types). Fruit were picked by hand and total weight and weight per 50 berries were recorded. The first picking date was defined as the first day when more than 100 g of fruit were harvested per plot. Half-pint samples were retained for shelf-life comparisons. Samples were placed in clamshell containers enclosed in sealed plastic bags, and held for 1–2 d at 2 °C, followed by 1–2 d at 18 °C. When gray mold started to appear, fruit samples were rated as a whole for appearance on a numerical scale of 1 to 5 (1 = unacceptable for use due to mold and leaky fruit, 2 = marginally acceptable for use, 3 = acceptable but with some flaws, 4 = attractive with only minor flaws, 5 = exceptional with no flaws or mold). Berries were then sorted to determine the percentage with visible gray mold.

Cane height was recorded each fall in primocane-fruiting plots. Cane height and length of winter dieback were recorded for 20 canes in each floricanefruiting plot as buds began to grow each May.

Yield, average berry weight, cane height and winter dieback data were analyzed by analysis of variance (ANOVA), and means were separated by a Fisher's protected least significant difference (LSD) at $\alpha = 0.05$ (SAS Institute, Cary, N.C.). For berry appearance and rot incidence, varieties were separated into an early group and late group based on maturity season. A two-factor ANOVA with variety as a main factor and harvest date as a repeated measurement factor was conducted separately for each of the 3 years using PROC MIXED procedure in SAS (SAS Institute). Comparisons between the varieties were conducted using only common harvest dates using contrast statements.

Each of the primocane- and floricanefruiting varieties was sampled for rosechafer beetles and two-spotted spider mites on 22 June 2000. Rosechafer beetle feeding was quantified by scoring the intensity of feeding injury. In each plot, four plants were randomly selected and the top half of these plants was scored on a numerical scale where 0 = no injury; 1 = light injury with small holes on a few leaves; 2 = medium injury on many leaves; 3 = medium injury on most leaves; and 4 = extensive injury on most leaves. A similar rating system was used to rate injury by two-spotted spider mites, with 0 = no injury and 4 = extensive injury on most of the leaves. Fisher's protected LSD test was used to compare mean injury ratings.

Raspberry varieties were rated visually for foliar and cane diseases on 7 Oct. 2001 and 12 Oct. 2002. Leafspot severity was estimated as the percent leaf area infected per plot. Anthracnose, spur blight and cane blight were rated as percent canes with at least one lesion out of 10 canes inspected per plot. Data were analyzed using one-way ANOVA in StatGraphics Plus 4.1 (Manugistics, Inc., Rockville, Md.) followed by mean separation using Fisher's protected LSD test ($\alpha = 0.05$). If data did not pass Bartlett's test for homogeneity of variance, they were $\log(x+1)$ or square-root transformed prior to analysis. Winter survival data were regressed against incidence of cane diseases using linear and nonlinear regression functions in StatGraphics Plus 4.1.

Results and discussion

PRIMOCANE-FRUITING VARIETIES. 'Caroline' was the highest yielding primocane-fruiting variety, averaging 6.1 t·ha⁻¹ over 3 years, followed by 'Autumn Bliss' (5.1 t·ha⁻¹), 'Dinkum' (4.3 t·ha⁻¹), 'Ruby' and 'Heritage' (3.9 t·ha⁻¹), and 'Autumn Britten' (2.4 t·ha⁻¹) (Table 1). 'Polana' could not be statistically compared to the other primocane-fruiting varieties because one of the three replications was planted 1 year later, but based on yields during the last two seasons when all plots were well established, 'Polana' was intermediate in productivity. 'Caroline', 'Autumn Bliss', and 'Autumn Britten' produced larger berries than 'Heritage' or 'Polana' (Table 1). 'Caroline' and 'Heritage' developed less postharvest gray mold than other varieties (Table 2).

Table 1. Yield and average berry weight of primocane-fruited raspberry varieties in Benton Harbor, Mich., in 2000–02.

Variety	Yield (t·ha ⁻¹) ^z			Berry wt (g) ^z		
	2000	2001	2002	2000	2001	2002
Autumn Bliss	4.8 ab ^z	6.0 ab	4.6 a	2.8 a	2.6 a	2.6 b
Autumn Britten	2.5 c	3.2 c	1.6 c	2.9 a	2.8 a	2.5 bc
Caroline	5.9 a	7.5 a	4.8 a	3.0 a	2.5 a	2.4 bc
Dinkum	4.7 ab	5.9 ab	2.3 bc	2.6 ab	2.4 a	2.4 bc
Heritage	2.8 c	5.9 ab	3.1 b	2.1 c	1.8 b	2.0 d
Polana		4.5 bc	3.2 b		1.9 b	2.2 cd
Ruby	3.9 bc	5.0 bc	2.9 bc	2.3 bc	2.6 a	3.0 a

^z1 t·ha⁻¹ = 0.4461 ton/acre; 1 g = 0.0353 oz.

^yMeans within columns followed by the same letter are not significantly different from each other based on Fisher's protected least significant difference test (0.05). 'Polana' data in 2000 were not included in the statistical analysis because one plot was missing.

'Autumn Bliss', 'Autumn Britten', and 'Polana' were the earliest maturing primocane-fruited varieties, producing the first ripe fruit almost 3 weeks before the standard variety, 'Heritage' (Table 2). 'Dinkum' and 'Caroline' ripened 7–9 d earlier than 'Heritage', and 'Ruby' ripened at the same time as 'Heritage'. The ripening sequence of the primocane-fruited varieties was generally consistent each year (data not shown) and similar to observations in Pennsylvania (Goulart and Demchak, 1999). Canes of 'Heritage' and 'Ruby' were the tallest, and 'Polana' canes were the shortest (Table 2). 'Polana' canes were less vigorous in other locations (Goulart and Demchak, 1999; Gwozdecki et al., 1996).

Growers often plant early- and late-fruited varieties to produce a consistent volume of fruit over an extending market season. 'Autumn Bliss' performed better than 'Autumn Britten' or 'Polana', the other two very early varieties. 'Autumn Bliss' was higher yielding and produced

berries as large as 'Autumn Britten'. 'Autumn Bliss' also produced relatively high yields and large berries in trials in New York (Weber et al., 2004a) and Pennsylvania (Goulart and Demchak, 1999). These three early varieties had significant fruit quality limitations. All were relatively susceptible to gray mold (Table 2). 'Autumn Bliss' and 'Autumn Britten' berries were somewhat crumbly, whereas 'Polana' berries were small.

Of the later-ripening primocane-fruited varieties ('Caroline', 'Dinkum', 'Heritage', and 'Ruby'), 'Caroline' was the most promising alternative to the commercial standard, 'Heritage'. 'Caroline' produced high yields of medium to large berries. 'Caroline' yields have been moderate (Weber et al., 2004a) and high (Goulart and Demchak, 1999) in other trials. 'Caroline' berries also had a low incidence of rot and were rated high in appearance after storage (Table 2). Although no measurements were made, pickers noted that 'Caroline' berries felt softer

than those of 'Heritage'. Harvest of 'Caroline' began several days before 'Heritage', which may be of value in areas with shorter growing seasons. 'Heritage' had little rot, but yields were only average and berries were small. 'Dinkum' and 'Ruby' produced average yields of larger berries that were susceptible to rot. 'Ruby' berries also tended to be crumbly. 'Dinkum' and 'Ruby' were not superior to 'Heritage' in fruit quality or productivity, and were not promising as alternatives to 'Heritage'.

Injury to primocane-fruited varieties from rosechafer beetle was extensive in 2000, reinforcing the need for growers to establish an insect management program during establishment of a new raspberry planting. Mean injury from rosechafer beetle (\pm SD) was highest on 'Caroline' (3.0 ± 1.0) and the lowest on 'Ruby' (1.0 ± 0.6), but means were not significantly different due to high variability between plots (data not shown). No two-spotted spider mite injury was found on leaves of these varieties.

There was generally more disease on the foliage and canes in 2002 than in 2001 (Table 3). This could have been due to favorable weather (more precipitation) or build-up of diseases over time in the planting or both. This allowed for more stringent screening conditions in 2002. The plants were treated with fungicides during both seasons, so we expect that even more disease would have developed in the absence of fungicide applications. Nonetheless disease levels were sufficient to compare the susceptibility of varieties. Leaf spot severity on primocane-fruited varieties was generally lower than

Table 2. Performance of primocane fruited raspberry varieties in Benton Harbor, Mich., including berry appearance and rot incidence after 2–5 d storage, and picking date and cane height (means of 3 years, 2000–02).

Variety	Appearance ^z			Rotten berries (%) ^z			First picking (days after Aug. 1)	Cane ht (m) ^y
	2000	2001	2002	2000	2001	2002		
Autumn Bliss	3.0 cb ^x	2.7 b	2.1 b	22 abc	17 ab	15 ab	6 c	1.2 bc
Autumn Britten	2.8 cd	2.9 ab	2.1 b	32 a	18 a	21 a	6 c	1.2 bc
Caroline	4.3 a	3.3 ab	2.6 ab	5 d	7 bc	4 c	17 b	1.2 bc
Dinkum	3.6 b	3.0 ab	2.3 ab	14 bcd	21 a	12 bc	15 b	1.1 cd
Heritage	3.6 b	3.4 a	2.3 ab	9 cd	6 c	5 c	24 a	1.3 ab
Polana	3.3 bc	3.0 ab	3.0 a	19 abcd	21 a	12 bc	6 c	1.0 d
Ruby	2.6 d	2.7 b	2.8 ab	27 ab	19 a	19 ab	26 a	1.4 a

^zAfter 1–4 d storage at 2 °C (35.6 °F) and 1 to 2 d at 18 °C (64.4 °F), overall appearance of fruit was rated from 1 (very unattractive) to 5 (excellent), and the percentage of rotten fruit was determined by counting moldy berries.

^y1 m = 3.2808 ft.

^xMeans followed by the same letter within columns are not significantly different from each other based on Fisher's protected least significant difference test (0.05).

Table 3. Disease susceptibility of raspberry varieties at Benton Harbor, Mich., in 2001–02.

Variety	Leaf spot (% leaf area affected)		Spur blight (% canes with symptoms)	
	2001 ^z	2002 ^z	2001	2002
Florican-fruited				
Boyne	0.5 ^y fgh ^x	7.0 ^y cde	1.7 d	6.7 ^w de
Canby	6.7 bc	12.3 ab	0.0 d	63.5 ab
Encore	11.0 ab	16.0 a	15.0 a	16.7 cde
Glen Ample	6.0 bcd	13.3 ab	0.0 d	10.0 cde
Killarney	4.3 bcd	10.0 abcd	0.0 d	6.7 de
Latham	0.3 gh	12.3 abc	0.0 d	13.3 cde
Lauren	2.0 def	6.3 de	0.0 d	3.3 e
Malahat	5.3 bcd	7.3 cde	3.3 cd	76.7 a
Nova	0.0 h	0.2 f	0.0 d	1.7 e
Prelude	2.3 def	16.7 a	0.0 d	33.3 cd
Qualicum	7.7 abc	16.7 a	1.7 d	36.7 bc
Reveille	1.5 efg	6.3 de	0.0 d	13.3 cde
Titan	3.0 cde	8.7 bcde	10.0 b	3.3 e
Tulameen	8.3 ab	5.7 e	0.0 d	13.3 cde
K81-6	15.0 a	11.3 abc	6.7 bc	70.0 a
Primocane-fruited				
Autumn Bliss	0.7 bc	2.7 ^y bc	0.0 d	90 a
Autumn Britten	0.2 c	2.0 cd	0.0 d	30 ab
Caroline	0.0 c	3.0 bc	3.3 cd	50 ab
Dinkum	1.2 b	4.3 ab	20.0 a	85 ab
Heritage	0.3 c	1.0 e	4.3 bc	10 ab
Polana ^y	2.0 a	6.7 a	7.7 b	55 ab
Ruby	0.0 c	1.3 de	0.0 d	50 b

^zDisease incidence and severity were visually estimated on 7 Oct. 2002 and 12 Oct. 2002.

^yActual data are shown, but analysis of variance (ANOVA) was done on log (x+1)-transformed data.

^xMeans followed by the same letter within columns (and fruiting type) are not significantly different from each other based on Fisher's protected least significant difference test (0.05).

^wActual data are shown, but ANOVA was done on square-root-transformed data.

Table 4. Berry yield, size, and picking dates of florican fruited raspberry varieties, Benton Harbor, Mich., in 2001–03.

Variety	Annual yield (t·ha ⁻¹) ^z	Avg berry wt (g) ^z	First picking (days after 15 June)		
			2001	2002	2003
Boyne	4.0 ^y abc	2.0 de	6 e	18 fg	21 b
Canby	3.6 bcd	2.1 cde	10 d	18 fg	23 b
Encore	2.6 def	2.7 ab	16 bc	24 d	24 b
Glen Ample	2.4 efg	2.8 a	16 bc	24 d	31 a
Killarney	4.7 ab	2.1 cde	12 cd	18 fg	22 b
Latham	3.3 cde	1.9 e	15 bc	28 a	34 a
Lauren	1.5 g	2.5 abc	13 cd	23 cd	24 b
Malahat	1.6 fg	2.3 bcde	14 c	20 ef	
Nova	3.3 cde	2.2 cde	6 e	16 g	16 c
Prelude	4.0 abc	2.3 bcde	3 e	13 h	12 d
Qualicum	1.7 fg	2.2 cde	18 b	25 bc	
Reveille	4.9 a	2.6 ab	3 e	16 g	12 d
Titan	2.3 efg	2.8 a	15 bc	22 de	23 b
Tulameen	1.4 g	2.4 abcd	24 a	26 ab	
K81-6	3.1 cde	2.8 a	18 b	26 ab	33 c

^z1 t·ha⁻¹ = 0.4461 ton/acre; 1 g = 0.0353 oz.

^yMeans followed by the same letter within columns are not significantly different from each other based on Fisher's protected least significant difference test (0.05).

on florican-fruited varieties in both years. 'Heritage' and 'Ruby' were most resistant to leaf spot, whereas 'Polana' and 'Dinkum' could be considered moderately resistant.

Spur blight was also more severe in 2002, but ratings were inconsistent from year to year (Table 3). The reason for the inconsistency is not clear, but may be related to confusion with other cane diseases, such as cane blight, or difficulty in distinguishing the disease from natural lignification. Ellis et al. (1991) stated that "spur blight lesions become indistinct and nearly undetectable later in the fall as primocanes turn brown after cork layers mature in preparation for winter." We rated plots in early October, which may have been past the optimal time for estimating spur blight incidence. Cane blight was confirmed in blackberries in the same planting, but not in raspberries. In general, 'Heritage' had the lowest spur blight ratings when averaged over both years, while 'Dinkum' appeared particularly susceptible. Anthracnose was not detected in primocane-fruited varieties.

FLORICANE-FRUITED VARIETIES.

The earliest-maturing florican-fruited varieties were 'Prelude', 'Nova', 'Reveille', 'Boyne', and 'Killarney' (Table 4). 'Reveille' and 'Killarney' were the highest yielding of this group. Varieties maturing mid-season included 'Canby', 'Latham', 'Lauren', 'Malahat', and 'Titan'. 'Canby' and 'Latham' were the most productive of this group, and 'Titan' and 'Lauren' produced the largest berries. The latest-maturing varieties were 'Encore', 'Glen Ample', 'Qualicum', 'Tulameen', and 'K81-6'. 'K81-6' was the highest-yielding late type, and 'Glen Ample' and 'K81-6' produced the largest fruit. Relative fruiting seasons were generally consistent with observations of some of the same varieties in New York (Weber et al., 2004b).

Winter injury to florican-fruited raspberry canes was moderate following a typical winter in 2000–01 (coldest temperature -21 °C on 13 and 22 Dec.), minimal after an extremely mild winter in 2001–02 (min. -15 °C on 5 Mar.), and severe following the 2002–03 winter when cold events occurred early in the winter (-16 °C on 3 Dec.) and late in the winter (-17 °C on 3 Mar.) (Table 5). 'Tulameen', 'Malahat', and 'Lauren' had substantial dieback each spring (Table 5)

and did not appear hardy enough for USDA Zone 6a (Cathey, 1990), such as southern Michigan. This trial site was elevated with excellent air flow so more injury might be expected on more marginal sites in this hardiness zone. ‘Canby’, ‘Encore’, ‘Glen Ample’, ‘Qualicum’, ‘Reveille’, ‘Titan’, and ‘K81-6’ sustained intermediate levels of injury. This group appears sufficiently hardy for warmer locations in southern Michigan where the standard variety ‘Canby’ can be grown successfully, but may be injured during unusually severe winters or when grown in less moderated locations. ‘Boyne’, ‘Killarney’, ‘Latham’, ‘Nova’, and ‘Prelude’ sustained minimal damage (Table 5), and are likely hardy enough for USDA Hardiness Zones 5 and 6 where ‘Boyne’ and ‘Latham’ can be grown successfully. Winter injury to ‘Prelude’ was not recorded in 2001 because canes exhibited dieback due to fruiting at the terminals the previous fall, which was not distinguished from winter injury when measurements were made.

Berry samples were rated for overall appearance and percent rot after a short storage period. In order to compare fruit from the same picking date, varieties were separated into early and late groups for analysis. In the early group (‘Boyne’, ‘Canby’, ‘Killarney’, ‘Latham’, ‘Nova’, ‘Prelude’, and ‘Reveille’), ‘Nova’ and ‘Prelude’ had the most attractive fruit (Table 6). ‘Nova’ had the least rot of the early varieties in 2 of 3 years. In the later group (‘Encore’, ‘Glen Ample’, ‘Lauren’, ‘Malahat’, ‘Qualicum’, ‘Titan’, ‘Tulameen’, and ‘K81-6’), ‘Qualicum’ tended to have the least rot and most attractive fruit (Table 7).

Plant injury to floricanes-fruiting varieties from rosechafer beetle was also extensive, with the greatest injury to Reveille (Table 8). This was significantly higher than the injury caused on ‘Encore’, ‘Killarney’, ‘Lauren’, ‘Prelude’, ‘Qualicum’, and ‘Tulameen’. Despite this variability in injury from rosechafer beetles, application of an insecticide to the planting prevented sufficient injury to cause noticeable horticultural effects. Leaf injury from two-spotted spider mites varied across varieties, and was greatest on ‘Glen Ample’ (Table 8). ‘Malahat’, ‘Prelude’, ‘Qualicum’, and ‘Tulameen’ had significantly less injury.

Leafspot severity varied widely on primocane-fruiting varieties, and was

Table 5. Cane height (mean of 3 years) and winter injury of floricanes-fruiting raspberry varieties at Benton Harbor, Mich., in 2001–03.

Variety	Cane ht (m) ^z	Winter injury (cm/cane) ^z		
		2001	2002	2003
Boyne	1.42 abcd ^y	5 d	2 b	3 g
Canby	1.44 abc	11 cd	3 b	63 bcde
Encore	1.23 de	4 d	1 b	25 fg
Glen Ample	1.28 bcde	6 d	1 b	55 cde
Killarney	1.27 cde	5 d	1 b	7 g
Latham	1.58 a	9 cd	0 b	6 g
Lauren	1.48 ab	23 bc	4 b	71 abcd
Malahat	1.24 de	31 b	20 a	79 abc
Nova	1.33 bcde	9 cd	2 b	2 g
Prelude	1.27 cde	--- ^x	0 b	2 g
Qualicum	1.29 bcde	15 cd	3 b	94 a
Reveille	1.34 bcd	4 d	0 b	11 g
Titan	1.31 bcde	15 cd	1 b	30 efg
Tulameen	1.13 e	59 a	19 a	89 ab
K81-6	1.24 de	5 d	3 b	44 def

^z1 m = 3.2808 ft; 1 cm = 0.3937 inch.

^yMeans followed by the same letter within columns are not significantly different from each other based on Fisher’s protected least significant difference test (0.05).

^xPrelude data were not collected in 2001 because winter injured tissue was not distinguished from portions that had died naturally after fruiting the previous fall.

Table 6. Percent rot and appearance rating of earlier-maturing floricanes-fruiting raspberry varieties following simulated commercial storage at Benton Harbor, Mich., in 2001–03.

Variety	Appearance ^z			Rotten berries (%) ^z		
	2001	2002	2003	2001	2002	2003
Boyne	3.3 a ^y	3.3 bc	1.8 c	30 a	2 b	23 a
Canby	3.4 a	3.3 b	1.9 bc	33 b	5 ab	21 ab
Killarney	3.5 a	3.3 bc	1.9 c	17 b	7 a	26 a
Nova	3.8 a	3.9 a	2.9 a	13 b	6 a	10 c
Prelude	3.3 a	3.8 ab	2.8 ab	25 ab	2 b	15 bc
Reveille	3.3 a	2.9 c	2.4 bc	34 a	6 a	23 a

^zAppearance rated from 1 (very unattractive) to 5 (excellent), and rotten fruit counted after 2 to 4 d storage at 2 °C (35.6 °F) and 1 to 2 d at 18 °C (64.4 °F).

^yMeans in a column followed by the same letter are not significantly different, Fisher’s protected least significant difference test (0.05).

Table 7. Percent rot and appearance rating of later-maturing floricanes-fruiting raspberry varieties following simulated commercial storage at Benton Harbor, Mich., in 2001–03.

Variety	Appearance ^z			Rotten berries (%) ^z		
	2001	2002	2003	2001	2002	2003
Encore	3.3 bc ^y	3.6 ab	2.3 b	29 a	3 bc	19 b
Glen Ample	3.6 ab	3.4 abcd	2.7 a	34 a	3 bc	6 d
Latham	3.6 ab	3.0 d	3.0 a	28 a	1 c	8 cd
Lauren	3.4 abc	3.4 bcd	2.1 b	31 a	10 a	24 ab
Malahat	3.3 c	3.4 abcd	2.4 b	35 a	4 bc	22 b
Qualicum	3.7 a	2.9 cd	2.6 b	25 a	5 bc	7 d
Titan	3.5 abc	3.3 bcd	2.1 b	34 a	7 ab	16 bc
Tulameen	3.3 bc	3.1 abcd	2.1 b	33 a	12 a	32 a
K81-6	3.6 a	3.7 a	2.2 b	42 a	9 ab	16 b

^zAppearance rated from 1 (very unattractive) to 5 (excellent), and rotten fruit counted after 2 to 4 d storage at 2 °C (35.6 °F) and 1 to 2 d at 18 °C (64.4 °F).

^yMeans in a column followed by the same letter are not significantly different, Fisher’s protected least significant difference test (0.05).

Table 8. Arthropod injury ratings of floricane fruiting raspberry varieties at Benton Harbor, Mich., in 2000.

Variety	Rosechafer beetle injury ^z	Two-spotted spider mite injury ^z
Boyne	1.3 ab ^y	2.0 ab
Canby	1.7 ab	2.0 ab
Encore	1.0 b	1.3 ab
Glen Ample	1.7 ab	3.3 a
Killarney	0.3 b	2.3 ab
Latham	1.7 ab	2.3 ab
Lauren	1.0 b	1.7 ab
Malahat	1.7 ab	1.0 b
Nova	1.7 ab	2.7 ab
Prelude	0.7 b	1.0 b
Qualicum	0.7 b	1.0 b
Reveille	3.0 a	2.7 ab
Titan	1.7 ab	1.3 ab
Tulameen	1.0 b	1.0 b
K81-6	1.3 ab	1.7 ab

^zVisual rating based on a scale of 0 (no injury) to 4 (extensive injury on most leaves).

^yMeans in a column followed by the same letter are not significantly different, Fisher's protected least significant difference test (0.05).

generally more severe in 2002 than 2001 (Table 3). 'Nova' was consistently highly resistant to leaf spot. 'Boyne', 'Lauren', 'Malahat', 'Reveille', 'Titan', and 'Tulameen' can be considered moderately resistant; 'Canby', 'Glen Ample', 'Killarney', 'Latham', and 'K81-6' moderately susceptible; and 'Encore', 'Prelude', and 'Qualicum' susceptible. Anthracnose on canes was only detected in 2002 on two varieties: 'Qualicum' (40% incidence) and 'Tulameen' (7%) (data not shown). Spur blight incidence varied widely between years and varieties. Most varieties had a low incidence of spur blight in 2001. 'Nova', 'Lauren', and 'Killarney' had low spur blight incidence in both years, and appeared the most resistant. In 2002, 'Canby', 'Malahat', and 'K81-6' had the highest spur blight ratings of

the group. Severe cane and leaf diseases may reduce winter hardiness (Ellis et al., 1991). Regressions of winter injury (Table 4) against anthracnose incidence alone and anthracnose and spur blight incidence combined were significant at $P = 0.05$, however, the R^2 values were low (26% to 28%). Research in Michigan has shown that when leaf and cane diseases in 'Tulameen' were effectively controlled with fungicides, winter survival of canes dramatically improved (A. Schilder, unpublished). Thus, some varieties that now appear marginally adapted to this region may perform better if disease levels are minimized.

Conclusion

Several newer primocane- and floricane-fruiting varieties appear to offer advantages over those currently grown in Michigan. 'Caroline' holds promise as a primocane-fruiting alternative to the standard varieties Heritage and Autumn Bliss. 'Caroline' also appeared fairly disease resistant under the conditions in this trial. 'Prelude' and 'Nova' showed promise as alternative early-season floricane-fruiting types, since they were as hardy and productive as the standard variety Boyne, but produced larger fruit. Again, both varieties are fairly disease resistant. Several summer-fruiting raspberries produced high-quality fruit and reasonable yields, and could become useful commercial varieties if they continue to perform well in subsequent years. No varieties were completely resistant to arthropod pests or diseases; however, some varieties sustained less injury and may be a good choice for growers wishing to minimize pesticide use. More research is needed to determine the role of cane and foliar diseases in winter injury in cold-climate regions.

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