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Adaptability of Floricane-fruiting Raspberry Cultivars to a High-elevation Arid Climate

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Abstract

Winter-hardy, high-yielding cultivars with good consumer acceptance and few production problems are critical to the economic viability of growing floricane-fruiting raspberries for local consumption in high elevation arid climates. A replicated trial was planted in 2006 to evaluate 16 floricane-fruiting cultivars for suitability to commercial production in the US Intermountain West. Factors evaluated included winter survival, yield, fruit size, fruiting season, consumer preference, and cane infestation by raspberry horntail, the most common cane-boring insect pest in northern Utah. The cultivars 'Royalty', 'Cascade Bounty', 'Georgia', 'Reveille' and 'Chemainus' had the highest cumulative yields over three seasons, which was correlated with a low incidence of visible winter injury. 'Royalty' and 'Chemainus' had fewer raspberry horntail larvae than 'Cascade Bounty' and 'Georgia'. Overall winter injury varied significantly across years, and was more closely correlated with severe temperature fluctuations than with absolute coldest winter temperature. These newer cultivars will provide alternatives to the current industry standard, 'Canby'.

Raspberries are a popular option for pick-your-own and pre-picked direct sales near urban centers throughout the U.S. Long before the recent local food movement, small scale berry farms throughout North America supplied local and regional markets. In some areas of the Intermountain West, fresh local raspberries are closely associated with the summer tourism industry, providing an important market opportunity. Some of these areas have challenging growing conditions associated with arid, high elevation (> 1,300 m) environments. These challenges include harsh winter temperatures, late spring and early fall frosts, alkaline soil and limited irrigation water that is often alkaline. Producers in these areas have come to rely heavily upon older floricane-fruiting cultivars with reasonable winter cold hardiness.

During the 1950s, the dominant raspberry cultivar grown in Utah was 'Latham', with some acreage of 'Newburgh' and 'Washington' (Barlow, 1963). Despite the relatively good winter hardiness of 'Latham', an estimated 50% of the raspberry crop from 1950 to 1960 was lost to floricane winter injury. When introduced to the region in the 1950s, the cultivar 'Canby' was quickly adopted (Barlow, 1963) due to superior fruit size and flavor, eventually displacing 'Latham' as the predominant cultivar, despite being less cold hardy. 'Canby' remained the predominant commercial cultivar in Utah until approximately 2001, when much of the commercial acreage was forced out of production due to an outbreak of Raspberry Bushy Dwarf Virus (RBDV) and Raspberry Mosaic Virus (Seeley et al., 2004; Robert Martin, personal communication).

Winter cane dieback remains a major limitation to floricane-fruiting raspberry production in the region, and growers in micro-

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climates with a sufficiently long frost-free period are planting more primocane-bearing cultivars. Although fully acclimated raspberry canes are hardy to -24°C to -30°C (Bushway et al., 2008; Crandall, 1994; Palonen and Lindén, 1999), research suggests that winter cane injury in red raspberries can result more from rapid temperature fluctuations than the absolute coldest winter temperature (Craig and Aalders, 1966; Zatylny et al., 1996). In addition, cane survival can be negatively influenced by desiccating winds (Crandall, 1994), which can be a serious problem in the arid Intermountain West.

Direct comparisons of raspberry cultivars typically focus on yield parameters (Finn et al., 2001; Garcekcioglu et al., 2005; Goulart, 1992; Kempler et al., 2005; 2006; Stephens et al., 2008), resistance to disease (Moore, 2004; 2006; Moore and Finn, 2007; Moore and Hoashi-Erhardt, 2012) and insect pests (Hanson et al., 2005; Kempler et al., 2007; Stephens et al., 2008). Somewhat more limited are cultivar trials evaluating cold tolerance. Work has been done to determine raspberry cold hardiness using controlled freezes (Hummer et al., 1995), but subsequent research showed that these were not well correlated with winter injury in the field (Zatylny et al., 1996).

Additional problems that are common to raspberry production in the Intermountain West include fruit sunburn due to high temperatures and high light intensity during the summer, and cane-boring insect pests. The raspberry horntail, *Hartigia cressonii* (Kirby), is the most common caneborer in commercial and home garden raspberry production in northern Utah (Alston et al., 2009). It is known in other western states, including California, Colorado, Idaho, Montana, Nevada and Washington (Middlekauff, 1969), but literature on its biology and management is scarce. There is no published information on the susceptibility or attractiveness of different summer-bearing raspberry cultivars to raspberry horntail.

The objective of this research was to evaluate floricane-fruiting cultivars for suitability to field production in the high elevation valleys of the Intermountain West. Sixteen cultivars were selected for trial. Cultivars included selections from the Pacific Northwest [‘Cascade Bounty’ (Moore and Finn, 2007), ‘Cascade Dawn’ (Moore, 2006), ‘Cascade Delight’ (Moore, 2004), ‘Chemainus’ (Kempler et al., 2006), ‘Coho’ (Finn et al., 2001), ‘Cowichan’ (Kempler et al., 2005), ‘Saanich’ (Kempler et al., 2007), ‘Tulameen’ (Daubeny and Anderson, 1991) and ‘Willamette’], New Zealand [‘Moutere’ (Stephens et al., 2008)], New York [‘Royalty’ (Sanford and Ourecky, 1982) and ‘Titan’ (Sanford et al., 1985)] and Maryland [‘Reveille’, ‘Lauren’ (Swartz et al., 1998) and ‘Georgia’]. ‘Georgia’ is a recent release from the University of Maryland (‘Glen Ample’ × PDW-4; US Plant Patent #19430) that is thought to be resistant to *Phytophthora* root rot (Swartz, personal communication). The Pacific Northwest cultivar ‘Canby’ was included as an industry standard. Because of the regional issues with RBDV, ‘Cowichan’ and ‘Willamette’ were included for putative resistance. Evaluation criteria were yield, fruiting season, fruit size, consumer acceptance, and susceptibility to the two primary problems in the region, winter injury and infestation by raspberry horntail.

Materials and Methods

Planting. A replicated raspberry cultivar trial was carried out at the Utah State University Agricultural Research Farm in Kaysville, Utah (41.01 N latitude, 1330 m elevation). The average freeze-free season is 165 d, with the average first fall freeze on 13 Oct (Moller and Gillies, 2008). The soil is a Kidman fine sandy loam with a pH of 7.5, and 1.5% organic matter. In April 2006, raspberry plants of 14 floricane-fruiting cultivars were obtained from commercial nurseries or from the breeder, and planted in four replicate plots arranged in a randomized block design with blocking by location within the field. Two additional cultivars, ‘Cascade Dawn’ and

'Cascade Delight' were planted in April 2007 in plots left vacant in the original randomization. Each plot was 3.66 m long, with 2.44 m space between plots in the row, and 3.05 m between rows. Each plot initially consisted of 6 nursery plants spaced 0.6 m apart within the row.

Cultural practices. The space between plots within the row was covered with landscape fabric (5 oz., Dewitt, Sikeston, MI) to suppress weeds and inhibit the raspberry cultivars from growing together. Alleyways were planted in the summer of 2006 to a 1:1 mix of perennial ryegrass (*Lolium perenne* L.) and creeping red fescue (*Festuca rubra* L.) at a seeding rate of 56 $kg \cdot ha^{-1}$. In-row weed control was a combination of annual applications of a pre-emergent herbicide (1.9 to 2.8 $L \cdot ha^{-1}$ Surflan, Southern Agric. Insecticides, Palmetto, FL) and hand weeding. The alleyway grass was mowed at ~ 3-week intervals, and 0.25 m strips were cultivated along the edges of the alleyways with a tractor-mounted multi-row rotary cultivator approximately three times per season to prevent grass from spreading into the raspberry row.

Plant nutrient needs were supplied with fertilizer applications of 135 $kg \cdot ha^{-1}$ of 16-16-16 NPK in mid-April and again in early June of each year, banded in the raspberry row. Cane thinning and pruning was according to typical regional practices, where spent floricanes were removed, and primocanes were thinned to approximately 10 to 12 canes per meter of row. Canes were supported with a trellis system consisting of two wires on each side of the row at approximately 0.25 and 0.9 m above the ground.

Irrigation was provided using both drip and overhead systems. A single drip tape (RO-DRIP Lo Flo, 15 cm emitter spacing, John Deere Water Irrigation Products, Moline, IL), was installed in the center of each row at planting. The system was designed to supply 1.9 $mm \cdot h^{-1}$ of irrigation to the 90-cm wide root zone. An overhead irrigation system was also installed to maintain the grass cover crop in the alleyways. The overhead system consisted of mini sprinklers (2.38 mm orifice, mini-Wobbler®, Senninger Irrigation, Inc., Clermont, FL) set at 2.4 m height, placed in every third row at a 9.1 m in-row spacing, and designed to supply 3.38 $mm \cdot h^{-1}$. Irrigation scheduling was based on crop needs calculated with evapotranspiration estimates from a nearby weather station, with approximately 25 mm per week applied through the overhead system and 17 to 25 mm per week applied by drip. The plots were not treated with insecticide in order to evaluate susceptibility to raspberry horntail.

Data collection. Each spring from 2007 to 2011, each plot was visually evaluated to quantify winter injury. Plots were rated for the percent of total bud survival. In the 2008-2010 growing seasons, plots were evaluated for total yield, fruit size, and timing of the production season. Ripe fruit in each plot was harvested three times per week, and total ripe fruit per plot weighed. For one harvest per week, mean fruit weight was determined for a 10-fruit subsample. These weekly mean fruit size values were used to calculate a weighted mean fruit size to represent the season.

Some plots produced a few ripe fruit sporadically for the first and last weeks of harvest, which were collected and weighed. However, to better characterize the production season, cumulative yield curves were generated, and the date at which 20% (early season) of the total season crop had been harvested was calculated for each plot and season. This seasonal benchmark was then used to compare cultivars for harvest season.

To compare fruit quality and consumer preference among cultivars, fruit were evaluated by an untrained panel and by customers at a farmers market as previously described (Black et al., 2013).

Approximately weekly from June to August in each of 2009 to 2011, primocanes with wilted tips and suspected of infestation with raspberry horntail were collected from each plot. Suspect canes were cut open to confirm the presence of raspberry horntail larvae.

A weather station located ~ 150 m from the plots recorded air temperature, humidity, wind speed, precipitation and solar radiation. Data were archived by the Utah Climate Center as part of their Fruit Grower data network (http://climate.usu.edu).

Data for yield, fruit size, harvest season, and raspberry horntail infestation for the three years were analyzed as repeated measures using the GLM or MIXED procedures in the SAS software package [versions 9.1 or 9.3 (horntail data), Cary, NC]. Analysis of cane survival scores was conducted on arcsin-transformed data, with LSMeans used to determined treatment means, and back-transformed data reported.

Results and Discussion

Winter injury. The 2007-2008 winter resulted in no visible winter injury in any of the cultivars, with the lowest winter temperatures of -16.9°C recorded on 22 Jan. In contrast, cane injury following the 2010-2011 winter was detected in every cultivar (Table 1), despite the coldest winter temperature of -15.9°C on 11 Jan. The injury was most likely due to a relatively mild fall, and then a hard freeze of -15°C on 25 November 2010 without any prior conditioning freezes. The day-time high just prior to this freeze was 9.6°C. Cane injury was also high after the 2006-2007 and the 2009-2010 winters following minimum winter temperatures of

Table 1. Winter floricane bud survival of summer-bearing cultivars at the USU Kaysville Research Farm. Evaluations are based on visual ratings of percent bud survival (% survival). Analysis was carried out on arcsin transformed data. Values reported are back-transformed. There was no visible winter injury in any of the cultivars in the spring of 2008.

	Floricane bud survival (%)					
Cultivar	2007	2008	2009	2010	2011	Mean
Royalty	100 a	100	100 a	100 a	90 ab	98.0
Cascade Bounty	93 bcd	100	100 a	96.1 ab	90 a	95.8
Moutere	88 cd	100	100 a	99.0 a	88 ab	95.0
Reveille	99 abc	100	99 a	99.0 a	73 bc	94.0
Cowichan	97 abcd	100	100 a	99.0 a	74 abc	94.0
Georgia	100 ab	100	100 a	96.5 ab	68 bc	92.9
Cascade Dawn	-	100	99 ab	97.6 ab	68 c	91.2
Cascade Delight	-	100	99 ab	98.0 ab	64 c	90.3
Saanich	82 de	100	94 bcd	97.6 ab	68 c	88.3
Canby	53 f	100	94 bcd	97.0 ab	75 abc	83.8
Chemainus	90 cd	100	92 cde	98.7 a	22 ef	80.5
Willamette	64 ef	100	84 de	77.8 cd	59 cd	77.0
Tulameen	88 cd	100	87 de	82.2 c	16 f	74.6
Titan	25 gh	100	99 ab	89.5 bc	40 de	70.7
Lauren	49 fg	100	81 e	42.4 f	20 ef	58.5
Coho	23 h	100	80 e	49.5 ef	30 ef	56.5
	<0.0001	n.s.	<0.0001	<0.0001	<0.0001	

Analysis of Variance	
Cultivar	<0.0001
Block	0.081
Year	<0.0001
Cultivar × Year	<0.0001

Within-year means separation by LSD. Cultivar means followed by the same letter are not significantly different at $P = 0.05$.

-18.6 and -17.9°C, respectively. In the winter of 2009-2010, temperatures plummeted from 13°C to -18°C within 12 hours on 10 December (data not shown). Similarly, in 2006-2007 temperatures dropped within a single day from 12.5°C to -18.6°C on 14 January (data not shown). The cultivars 'Royalty' and 'Cascade Bounty' consistently showed winter survival greater than 90% (Table 1). The least cold hardy of the cultivars were 'Coho' and 'Lauren'.

Yield. The cultivar 'Canby', Utah's industry standard, ranged in marketable yield from 0.52 to 2.3 kg·m^{-1} (1.71 to 7.54 Mg·ha^{-1}), with a 3 year average of 1.49 kg·m^{-1} (Fig. 1). These total yields are similar to those previously reported for Southwestern (Bozeman) Montana (Lockerman et al., 1986) and Benton Harbor, Michigan (Hanson et al., 2005), but are lower than those reported for Western (Corvallis) Montana (Lockerman et al., 1986) and Turkey (Garcekcioglu et al., 2005). The lower yields seen in Utah, Southwestern Montana and Michigan are most likely due to 'Canby's' susceptibility to winter cane injury. The location in Southwestern Montana is at a similar elevation (1460 m) to the Kaysville location, whereas the Western Montana location is much lower elevation (1060 m). Some cultivars that performed better than 'Canby' in Utah were 'Royalty', 'Cascade Bounty', 'Reveille' and 'Cowichan'. In contrast, 'Willamette', 'Tulameen', 'Coho' and 'Lauren' all had yields lower than 'Canby' and also showed a higher degree of winter injury. There was a significant year × cultivar interaction, which showed some correlation to winter injury susceptibility. In general, those cultivars with the lowest degree of winter injury typically produced the most consistent yields. There were obvious exceptions, including 'Cascade Dawn' which showed relatively high winter survival but low yields. It should be noted that 'Cascade Dawn' and

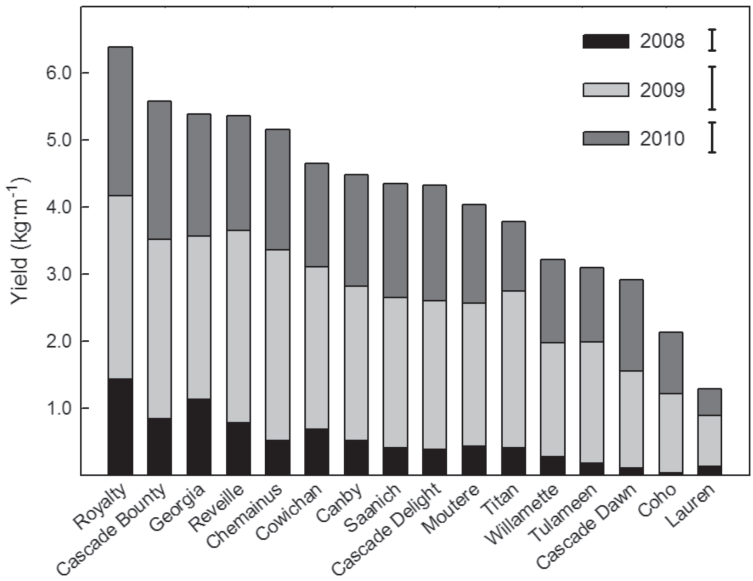

Fig. 1. Total marketable yield of 16 floricane-fruiting raspberry cultivars over three seasons (2008-2010) at the Kaysville Research Farm, Kaysville, UT. Yield values are expressed as kg of marketable fruit per linear m of row (kg·m^{-1}). Based on the row spacing used here 1 kg·m^{-1} is equivalent to 3.28 Mg·ha^{-1}. Yield showed a significant cultivar × year interaction (<0.001) and values for each year were analyzed independently. Vertical error bars show least significant difference (LSD) within each year.

'Cascade Delight' were planted one year later than the other cultivars, and so yields were evaluated in the 2nd through the 4th seasons, compared to the 3rd through the 5th seasons for the remaining cultivars.

In the Pacific Northwest, where growing conditions are generally more favorable, yield is often higher than what we observed in Utah. For example, one of the highest yielding cultivars in this study was 'Cascade Bounty' with a 3-year average of 1.86 $kg \cdot m^{-1}$ (6.10 $Mg \cdot ha^{-1}$), compared to 25.5 $Mg \cdot ha^{-1}$ reported for Puyallup, Washington (Moore and Finn, 2007). Similarly, 'Cascade Delight' grown in Utah yielded 29% of that observed in the same Washington study. This difference was fairly typical as 'Saanich' grown in Utah yielded 28% of that observed in Abbotsford, British Columbia (Kempler et al., 2007), 'Chemainus' and 'Cowichan' yielded 46 and 43% (respectively) of that reported in British Columbia (Kempler et al., 2005; Stephens et al., 2008). The severity of winter injury in several years, coupled with the lack of any temperatures below previously published minimums (Bushway et al., 2008; Crandall, 1994; Palonen and Lindén, 1999) throughout the life of the planting suggest that the coldest winter temperatures are not responsible for the winter injury observed here. Rather, injury is more likely due to rapid temperature drops in the fall and rapid fluctuations that cause dehardening during the winter. These results are in agreement with previous studies in northeastern North America (Craig and Aalders, 1966; Zatylny et al., 1996).

Fruit sunburn. The amount of total fruit that was considered unmarketable was not recorded at most harvests, as only marketable fruit was harvested. The most common cause for unmarketable fruit was sunburn, followed by inadequate size, or the fruit becoming over ripe. Over-ripe fruit was most commonly found after the weekend, when the harvest interval was more than 2 d. To quantify sunburn susceptibility, a 20-fruit sample was collected from each plot on five harvest dates in 2011, and the number of fruits showing sunburn were counted. Because some cultivars and some replicate plots within cultivars did not produce fruit during this period, detecting statistical differences in sunburn frequency was not possible. Among fruiting plots, the highest incidence of sunburn occurred in plots of 'Reveille' followed by 'Royalty' and 'Cascade Delight'. Among cultivars that were producing fruit, 'Cowichan' had the lowest incidence of sunburn, followed by 'Cascade Bounty', 'Canby', 'Willamette' and 'Saanich' (data not shown).

Harvest season. The harvest season, as indexed by the date at which 20% of the total season yields was reached, showed a significant cultivar × year interaction (Table 2). Some of this interaction may have been due to cultivars that showed the greatest seasonal variability in yields. Cultivars that had more severe winter injury tended to produce most of their fruit on basal buds, due to the loss of terminal and median buds, which could have altered the harvest season. The cultivar 'Coho', for example, showed significant winter injury in 2010 and had a fruit ripening season 11 days later than 'Canby' for that season. By comparison, there was no detectable winter injury in 2008, and low yields in 'Coho' were related to poor stand establishment. The 2008 fruiting season for 'Coho' was only 4 days later than that of 'Canby'. Among cultivars that showed more consistent harvest season, 'Reveille', 'Canby' and 'Moutere' were among the earliest, whereas 'Royalty' and 'Saanich' averaged 9 to 12 days later.

Fruit size and quality. Average fruit size also showed a highly significant cultivar × year interaction (Table 3), which appears to have been influenced by both crop load and winter injury. One might expect fruit size to be negatively correlated with crop load. However, where crop load reductions resulted from the loss of the most productive median-cane buds (Funt, 2013), fruit size potential would also be reduced. Of those cultivars showing more consistency across years, 'Cascade Delight' had the largest fruit,

Table 2. Harvest season of floricane fruiting raspberries as indexed by early harvest. Cumulative yields were calculated with early harvest representing the mean date at which cumulative yield reached 20% of the season total. Relative date is expressed as earliness relative to 'Canby'.

	Early harvest (20% of cumulative yield)				Relative
	2008	2009	2010	Mean	date
Reveille	7-Jul a	30-Jun a	12-Jul a	6-Jul	-4
Canby	14-Jul b	4-Jul b	12-Jul a	10-Jul	0
Moutere	15-Jul b	5-Jul bc	13-Jul ab	11-Jul	1
Lauren	13-Jul b	7-Jul cd	14-Jul bc	11-Jul	1
Cascade Dawn	14-Jul b	8-Jul cd	14-Jul bc	12-Jul	2
Titan	15-Jul b	7-Jul bcd	15-Jul c	12-Jul	2
Willamette	14-Jul b	9-Jul d	15-Jul c	12-Jul	2
Georgia	19-Jul bc	6-Jul bc	14-Jul bc	13-Jul	3
Cowichan	15-Jul b	8-Jul cd	17-Jul d	13-Jul	3
Chemainus	19-Jul bc	9-Jul d	15-Jul c	14-Jul	4
Cascade Delight	16-Jul b	12-Jul e	18-Jul de	15-Jul	5
Cascade Bounty	17-Jul bc	12-Jul e	20-Jul fg	16-Jul	6
Tulameen	20-Jul cd	15-Jul f	20-Jul fg	18-Jul	8
Saanich	24-Jul e	13-Jul ef	19-Jul ef	19-Jul	9
Royalty	22-Jul de	15-Jul f	21-Jul g	19-Jul	9
Coho	18-Jul bc	18-Jul g	25-Jul h	20-Jul	10
Mean	16-Jul	9-Jul	16-Jul		
Analysis of variance					
Cultivar	<0.001				
Rep	0.262				
Year	<0.001				
Cultivar*Year	<0.001				

Within-year means separation by LSD. Cultivar means followed by the same letter are not significantly different at $P = 0.05$.

whereas 'Reveille' and 'Canby' had among the smallest. Two different methods were used to evaluate consumer preference among cultivars. Unlike the results of a previous study however (Black et al., 2013), there was very little agreement between the two methods so that no clear preferences could be detected (data not shown).

Raspberry horntail. The average number of canes infested with raspberry horntail ranged from 0.8 to 19.5 per m of row (Table 4). The cultivars 'Saanich', 'Willamette' and 'Titan' were the most attractive and/or susceptible to the raspberry horntail, whereas, 'Royalty', 'Moutere', and 'Cascade Dawn' were the least attractive. These results differ from a previous study with primocane-fruiting cultivars, where there was no statistically significant difference among cultivars (Black et al., 2013). However, infestation rates in primocane-fruiting cultivars were much lower, likely due to pruning all canes to the ground each fall. The particularly low infestation rate for 'Royalty' is interesting in light of previous observations that this purple-fruited cultivar is immune or resistant to three species of aphids (Sanford and Ourecky, 1982).

Observations while collecting horntail-infested canes suggest that this cane-borer prefers thicker, sturdy canes as compared to thin, flexible ones. This observation is reasonable in light of the horntail's biology. The mature larva tunnels downward through the cane pith to construct an overwintering chamber. A thin cane may not support good

Table 3. Average fruit size (g/fruit) of floricane-fruiting raspberry cultivars at the USU Kaysville farm. Fruit weights were based on a 10-fruit random sample taken weekly, with a weighted average calculated over the season.

	Fruit size (g/fruit)			
Cultivar	2008	2009	2010	Mean
Cascade Delight	2.89 a	2.35 a	2.24 a	2.49
Tulameen	2.65 ab	1.91 bcd	2.05 ab	2.20
Cowichan	2.19 bcd	2.01 bc	2.06 ab	2.08
Royalty	2.36 bc	1.67 defg	1.95 abc	1.99
Titan	1.94 cde	1.92 bcd	1.87 bcd	1.91
Georgia	2.20 bcd	1.63 efg	1.72 cdef	1.85
Chemainus	2.09 cde	1.55 fg	1.89 bcd	1.84
Willamette	1.97 cde	1.95 bc	1.59 def	1.84
Moutere	1.99 cde	1.61 efg	1.81 bcde	1.80
Cascade Dawn	1.63 e	1.83 bcde	1.79 bcde	1.75
Coho	2.30 bcd	1.43 g	1.46 f	1.73
Reveille	1.61 e	1.78 cdef	1.72 cdef	1.70
Canby	2.04 cde	1.41 g	1.64 cdef	1.70
Saanich	2.10 cde	1.40 g	1.55 ef	1.68
Cascade Bounty	1.62 e	1.62 efg	1.73 cdef	1.65
Lauren	1.80 de	2.07 b	1.07 g	1.65
Analysis of variance				
Cultivar	<0.001			
Rep	<0.001			
Year	<0.001			
Cultivar × Year	<0.001			

Within-year means separation by LSD. Cultivar means followed by the same letter are not significantly different at $P = 0.05$.

horntail survival. Some cultivars with high winter hardiness and cane vigor were least susceptible to raspberry horntail attack, such as 'Royalty', 'Moutere' and 'Cowichan'. In contrast, cultivars with low hardiness and vigor were more susceptible to horntail, such as 'Willamette' and 'Titan'. However, in other cases, hardiness and vigor did not correlate to susceptibility to horntail.

Growing raspberries in an arid continental climate above 1300 m elevation presents a number of challenges, one of the most difficult being winter cane injury. In this study, there was no relationship between severity of floricane damage and the coldest recorded winter temperature. Seasons with more pronounced winter damage were more typically associated with rapid temperature drops. Although primocane-fruiting cultivars can avoid winter injury through fall-only cropping, many areas in the Intermountain West do not have a long enough growing season for consistent fall crops (Black et al., 2013). Opportunities for local direct sales of raspberries remain a strong incentive for diversified small-acreage operators. Although marketable yields of the 16 cultivars reported here were much lower than reported for the major raspberry producing areas of the Pacific Northwest, results are similar to those reported for similar challenging climates. The cultivars 'Royalty', 'Cascade Bounty', 'Georgia', 'Reveille' and 'Chemainus' had the highest cumulative yields over three seasons, which corresponded with lower rates of winter injury. 'Cascade Bounty' was less

Table 4. Horntail larval infestation of summer raspberry canes (number per row meter) at Kaysville for 2009-2011.

Cultivar	Horntail laval infestation (no./row m)
Royalty	0.82 ± 0.33 a
Moutere	2.62 ± 0.82 ab
Cascade Dawn	4.10 ± 0.98 ab
Cowichan	5.09 ± 0.82 abc
Coho	5.25 ± 1.80 abc
Cascade Delight	5.74 ± 1.31 abc
Lauren	6.07 ± 2.13 abcd
Tulameen	7.22 ± 0.98 abcde
Reveille	9.35 ± 1.80 bcde
Chemainus	9.68 ± 2.13 bcde
Canby	10.66 ± 2.46 cde
Georgia	11.98 ± 2.46 cde
Cascade Bounty	12.30 ± 2.30 cdef
Titan	13.45 ± 3.94 def
Willamette	16.73 ± 3.94 ef
Saanich	19.52 ± 4.59 f

susceptible to fruit sunburn while 'Royalty' was prone to sunburn. 'Royalty' and 'Chemainus' were less impacted by raspberry horntail, but 'Cascade Bounty' and 'Georgia' were attractive to this cane-borer. This is the first report comparing horntail preference among floricane-fruiting raspberry. These top-performing floricane-fruiting cultivars will provide alternatives for raspberry producers in the Intermountain West and similar challenging environments.

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