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Fruit Varieties Journal 49(1):52-58 1995

Cold Hardiness in *Rubus*[1]

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Abstract

More than 80 raspberry and 42 blackberry genotypes were evaluated for cold hardiness after controlled laboratory freezing in January 1990. Red, yellow, black, and purple raspberry cultivars (*R. idaeus* L., *R. neglectus* Peck), blackberry cultivars (*R. allegheniensis* Porter, *R. ursinus* Cham & Schldl.) and other *Rubus* species selections were examined. T_{50}'s, the temperatures where 50% of the samples were killed, were calculated for cane (cambial region), bud and bud base of each genotype. Red, purple, and black raspberries had a lower T_{50} values than did blackberries. The T_{50} value of *Rubus idaeus* L. cv. Burnetholm canes was -34C. Hardy summer bearing red raspberries, 'Canby' and 'Puyallup' had a T_{50} value of -30C; 'Canby' buds -26C; Puyallup -20C. The T_{50} values of fall fruiting red raspberries, such as 'Zeva Remontante,' 'Indian Summer,' 'St. Regis,' and 'Fallred,' ranged from -23 to -25C. Several purple raspberries (*Rubus neglectus* Peck cvs. Brandywine, Royalty) were quite cane hardy, with T_{50} values lower than -33C. The buds and bud bases of these purple raspberries, however, had T_{50} values at most -25C. Canes of several black raspberries (*R. occidentalis* L. cvs. New Logan, Bristol) had T_{50} values of -28C; buds -27C and -17C, respectively. 'Bristol' offspring had T_{50} values as much as 15C less than the parent. Canes of the hardiest blackberry cultivar, (*R. sp.* cv. Black Satin) had a T_{50} value of -23C; buds were -19C. In many raspberry and some species genotypes examined, the region of the bud at the axis at the cane was less hardy than were tissues within the bud scales. The T_{50} values of canes of most cultivars ranged from about 2 to 15 degrees hardier than buds.

Introduction

Interest in *Rubus* cold hardiness has been increasing in recent years all around the world and particularly in the Pacific Northwest due to cold winters which have caused economic injury to caneberry crops. Despite occasional low killing temperatures, producers want to extend the production range of many types of raspberries, hybrid berries and blackberries to more northerly environments or stabilize production in present areas. Researchers have begun screening to determine which cultivars match those needs.

Several techniques have been used to select for cold hardiness. Sakai et al. (9) established a pre-conditioning treatment to determine the "maximum mid-winter cold hardiness" level in plants. This pre-conditioning regime was applied in this study. Other scientists (4) feel that this regime evaluates the capacity of plants to acclimatize to the control conditions. We used this regime as a standardization procedure, and will refer to the T_{50} values as relative hardiness measurements.

Freezing injury to raspberries (1, 11) and trailing blackberries (1) has

[1]This project was partially sponsored by a grant from USDA-ARS Germplasm Evaluation Funds and is a contribution of the Oregon Agricultural Experiment Station in cooperation.
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been assessed after winters when especially low temperatures occurred. Hardiness has also been evaluated after laboratory freezing tests by a number of techniques. Warmund et al. (14) determined cold hardiness of six blackberry cultivars by evaluating oxidative browning after laboratory freezing. Warmund et al. (15) and Warmund and George (12, 13) contrasted the use of differential thermal analysis with T_{50} values, the temperature where 50% of the samples were killed, in estimating hardiness of blackberry buds. Hummel and Moore (5) reported on the hardiness of red raspberry cultivars also using T_{50} determinations from visual rating of oxidative browning after laboratory freezing.

Most tests have reported on a limited number of cultivars within one crop group. The Corvallis Repository preserved a large *Rubus* field collection with selections from many species. Besides cultivated sorts this field included *R. hirtus* Waldst. & Kit., *R. parvifolius* L., *R. pungens* Cambess., and *R. microphyllus* L. and many other species. We examined these cultivated and wild genotypes to contrast survivability between and within crop groupings. The objective of our study was to determine the relative cold hardiness of the cambial region of canes, dormant buds, and the axillary attachment point of the dormant bud (bud base) for a selections of raspberries, blackberries, and hybrid berries.

Materials and Methods

A procedure modified from Sakai et al. (9) and similar to that used by Warmund et al. (15) and Hummer et al. (6) was used to estimate maximum mid-winter cold hardiness. During January 1990, 122 genotypes of *Rubus* were sampled over an 11 day period from field plantings at the USDA-ARS National Clonal Germplasm Repository, Corvallis, Ore. Plants were trellised to a height of 1.5 m during the previous summer. Four to 5 canes per genotype were cut approximately 4 cm above the ground, placed into polyethylene bags, and transported to the laboratory at Oregon State University for sample preparation. Samples were cut from the mid-portion of each cane. Sections, about 6 cm long with at least 1 bud, were used as replicates. Samples were randomly sorted with 5 replicates allocated to each of 9 test temperature treatments: a control (no laboratory freezing, held at 4C), -5, -10, -15, -20, -25, -30, -35, and -40C. All samples were wrapped in moistened cheesecloth to initiate ice nucleation, placed in aluminum foil, labeled, and stored at -2 C for 27 days.

On the 27th day, samples were removed from storage and placed in the Revco Ultralow Freezer. Copper-constantan 22-gauge thermocouples connected to an Adtronics Microcool control system (Springfield, Oregon) measured the temperature inside of the samples placed in the freezing chamber. The freezer remained at -2C for 12 hours and then the temperature dropped at 5C per hour. Five replicate cane pieces for each genotype were removed at each test temperature and thawed overnight at 4C. The following day, basal ends of the cane sections were placed in flats of perlite under mist in a greenhouse at 22C day/15C night temperature for 2 weeks. No supplemental lighting was used.

The cambial region of the cane, bud axes, and bud primordia were evaluated for oxidative browning. Ratings of 1 (no discoloration) to 5 (complete browning) were taken. The canes were evaluated by removing a thin layer of phloem with a razor blade, and assessing the color in the cambial region remaining attached to the xylem. Dormant buds were dissected longitudinally to assess browning in the bud tissues and the region of axillary bud attachment to the cane was rated separately. Sample tissues with a rating of 4 or 5 were judged to be dead.

A modified Spearman-Karber equation as described in Bittenbender and Howell (2) determined T_{50} values for the samples. This statistic estimates the temperature at which 50% of the samples were killed. Lowest survival temperatures were also calculated, however, the modified T_{50} tended to be a more conservative hardiness estimator and was thus chosen to be reported here as the hardiness level achieved by the tissue.

Ambient air temperature was monitored in the field by a recording hygrothermograph, supplemented with meteorological data taken at Hyslop Field Laboratory, Oregon State University, Corvallis, Oregon. The lowest temperature of the winter was -17C, on 21 December 1990. The plants had received more than 1000 hours of chilling before sampling.

Rubus is a very diverse and complex genus encompassing 12 subgenera and many crop groupings. Two subgenera of horticultural interest were examined in this study. In this discussion, the cultivars and species were divided into three groups: red raspberries, black and purple raspberries, blackberries and hybrid berries. The red raspberries, subgenus *Idaeobatus,* included 'Burnetholm' derived from the European red raspberry, *R. idaeus* L., and others derived from a complex of the European and the North American red raspberry, *R. strigosus* Michx. The black and purple raspberry group included derivatives of *R. occidentalis* L., found in eastern North America, and *R. leucodermis* Dougl. in the west. The purple raspberries are black raspberry by red raspberry crosses. Blackberry genotypes, subgenus *Rubus* (formerly termed *Eubatus* Focke), included members of the section *Moriferi,* the European and eastern North American blackberries, and the section *Ursini,* the western North American blackberries. The hybrid berries, blackberry by red raspberry crosses, are discussed here with the blackberries.

Results and Discussion

In agreement with other research (1, 5, 10), most raspberries had lower T_{50} values than did blackberries or black raspberries (Table 1, 3, 4). Purple raspberries, which are a combination of red and black raspberries, were intermediate (Table 1, 3, 4). Surviving buds on canes began to break under the greenhouse conditions so this indicated that rest was satisfied.

Red Raspberries. The canes of the red raspberries, as a group, were hardiest (Table 1). The bud bases and buds of many of the cultivars sampled had higher T_{50} values than did the cane. 'Burnetholm,' one of the hardiest red raspberries tested, is a chance seedling of *R. idaeus* from Scotland. Canes of another hardy raspberry, 'Canby,' had a T_{50} value of -30 and its buds -26C.

The T_{50} value of canes of the red raspberry cvs. Indian Summer, Scepter, St. Regis, and Fall Red, were midrange, -23C. These are primocane fruiting types and are usually pruned to ground level so winter damage to above ground canes is unimportant. The least cold hardy red raspberry cvs. included Willamette whose canes survived -17C.

While a thorough examination of species variability was not performed, hardiness levels of representatives of idaeobatus species were determined (Table 2). Canes of the available specimens of Asian species: *R. hirtus* Waldst. & Kit., *R. parvifolius* L., *R. pungens* Cambess., and *R. microphyllus* L. were the least hardy of the species tested.

Purple and black raspberries. The T_{50} values for canes of two purple raspberries, *R. sp.* 'Brandywine' and 'Royalty' was -33C (Table 3), and along with the red raspberry 'Burnetholm,' are considered to be the hardiest genotypes studied.

The two hardiest black raspberries were the 'New Logan' and 'Bristol' whose canes had T_{50} values of -28C. 'Bristol,' released from New York in 1938, is a leading cultivar noted for

Table 1. T_{50} values of red raspberry cultivars after laboratory freezing in January 1990.

Hardiness level and cultivars	Pedigree	T_{50} Stem	T_{50} Bud	T_{50} Bud base
Burnetholm	*R. Idaeus* selection	-34	-30	-23
Malling Promise	complex derivative of Newburgh, Pynes Royal, Lloyd George	-32	-11	- 9
Durham	Taylor x Nector	-32	-19	-22
Puyallup	Washington x Taylor	-31	-18	-20
Norna	Preussen x Lloyd George	-30	-18	-24
Sentry	Sunrise x Taylor	-30	-16	-23
Canby	Viking x Lloyd George	-30	-25	-26
Phoenix	*R. idaeus* selection	-29	-15	-18
Boyne	Indian Summer x Chief	-28	-23	-25
Nootka	Carnival x Willamette	-27	-18	-20
Killarney	Indian Summer x Chief	-27	-17	-19
Malling Exploit	complex derivative of Newburgh, Lloyd George, Pynes Royal	-27	-19	-18
Rossana	Malling Promise seedling	-27	-18	-18
Liberty	Sunrise S2 x Newburgh	-26	-15	-16
Zeva Remontante	(Romy x Indian Summer) x Romy	-26	-17	-18
Meeker	Willamette x Cuthbert	-25	-22	-22
Fairview	ORUS 782 x Washington	-25	-24	-23
Milton	Lloyd George x Newburgh	-25	-25	-25
Pursley	*R. idaeus* selection	-24	- 3	-23
Viking	Cuthbert x Marlboro	-24	- 8	- 9
Amber (yellow)	Taylor x Cuthbert	-24	-10	- 9
Indian Summer	(Empire x Herbert) x Lloyd George	-24	-17	-20
Newburgh	Newman x Herbert	-24	-13	-11
Scepter	September x Durham	-23	-24	-24
Cuthbert	*R. strigosus* selection	-23	-23	-25
St. Regis	*R. strigosus* selection	-23	-17	-19
Fallred	NH 7 x NY 287	-23	-19	-20
Newman	*R. strigosus* selection	-23	-16	-17
Baumforth Std. A	Fillbasket seedling selection	-24	-21	-21
Chilcotin	Sumner x Newburgh	-22	-20	-20
Haida	Malling Promise x Creston	-22	-14	-15
Jingu Juegal	*R. crataegifolius* selection	-21	-12	- 5
Rubin Bulgarski	Lloyd George x Preussen	-21	-15	-16
Skeena	Creston x SHRI 6010/52	-21	-19	-18
Malling Leo	*R. idaeus* complex	-20	-11	-11
Creston	*R. strigosus* selection	-20	-21	-25
Reveille	(Indian Summer x Sunrise) x September	-20	-22	-19
Washington	Cuthbert x Lloyd George	-20	-23	-24
Rideau	Lloyd George x Newman	-18	-28	-25
Chief	Newburgh seedling selection	-18	-13	-12
Willamette	Newburgh x Lloyd George	-17	-15	-16
Pocahontas	Hilton x (Taylor x Ranere)	-17	-12	- 8
Sunrise	Latham x Ranere	-16	-15	-13
Amity	(Fallred x ORUS 1347) x (Malling 791/45 x Heritage)	-16	-15	-16
Mandarin	(*R. parvifolus* x Taylor) x Newburgh	-15	-21	-20
Matsqui	Sumner x Carnival	-15	-17	-18
Defiance	Red Antwerp x Fillbasket	-14	- 5	- 5
Sentinel	Sunrise x Milton	-12	-22	-21
Malling Landmark	Preussen x Baumforth A	-12	- 2	- 3

[z]These values were calculated from 5 replicates treated at -5, -10, -15, -20, -25, -30, -35, -40C and a control stored at 4C.

Table 2. T_{50} of *Rubus* species after laboratory freezing in January 1990.[z]

Rubus species	NCGR Accession number	Origin	T_{50} Stem	T_{50} Bud	T_{50} Bud base
R. crataegifolus Bunge	963	Korea	-24	-18	-17
R. flosculosus Focke	424	China	-31	-15	-15
R. hirtus Waldst. & Kit.	59	Yugoslavia	-18	-16	-14
R. idaeus L.	142	Serbia	-25	- 4	- 2
R. lasiostylus Focke	246	China	-25	-16	-16
R. lasiostylus v. *hubeiensis* Yu	426	China	-25	- 7	- 1
R. leucodermis Doug.	599	Oregon	-22	-25	-25
R. microphyllus L.	158	Japan	-13	-13	-13
R. neomexicanus A. Gray	58	Southwest USA	-19	-13	-13
R. occidentalis L.	729	North Carolina	-18	-17	-19
R. occidentalis L.	733	North Carolina	-17	-14	-17
R. parvifolius L.	184	Asia	-14	-16	-16
R. phoenicolasius Maxim.	63	Japan	-26	-13	-13
R. pungens Cambess.	966	Asia	-13	-16	-16
R. spectabilis Purch	4	California	-26	-14	-14
R. strigosus Michx.	1016	Wyoming	-19	-16	-14
R. strigosus Michx.	17	Washington	-25	- 4	-15
R. thibetanus Franch.	264	Asia	-27	-18	-18

[z]These values were calculated from 5 replicates treated at -5, -10, -15, -20, -25, -30, -35, -40C and a control stored at 4C.

plant vigor and fruit size (7). The cultivars 'Lowden,' 'Allen,' and 'Jewel' are each derivatives of 'Bristol.' None of these three cultivars developed a level of hardiness comparable to that of the parent.

While one selection from the northern range of *R. occidentalis* was the hardiest black raspberry, cane selections of *R. leucodermis* from Oregon and Washington survived lower temperatures than did canes of *R. occidentalis* from North Carolina, 'Plum Farmer,' or 'Shuttleworth' (Table 2, 3).

Blackberries and Hybrid Berries. T_{50} values for blackberries canes ranged from -25 to -10C (Table 4) and were about 10C higher than those of the red

Table 3. T_{50} Values of black and purple raspberries after laboratory freezing in January 1990.[z]

Cultivars	Pedigree	T_{50} Stem	T_{50} Bud	T_{50} Bud base
Brandywine	NY 631 x Hilton	-34	-21	-20
Royalty	(Cumb. x Newburgh) x (Newburgh x Indian Summer)	-33	-25	-25
New Logan	*R. occidentalis* selection	-28	-21	-27
Bristol	Watson Prolific x Honeysweet	-28	-17	-17
Munger	Shaffer open-pollinated	-24	-12	-12
Clyde	Bristol x (Newburgh x Indian Summer)	-20	-23	-24
Amethyst	Robertson x Cuthbert	-20	-17	-18
Lowden	Bristol x Sodus	-19	-10	-10
Plum Farmer	*R. occidentalis* selection	-19	-12	-12
Allen	Bristol x Cumberland	-18	-13	-10
Jewel	(Bristol x Dundee) x Dundee	-13	-12	-14
Shuttleworth	*R. occidentalis* selection	-10	-19	-19

[z]These values were calculated from 5 replicates treated at -5, -10, -15, -20, -25, -30, -35, -40C and a control stored at 4C.

Table 4. T_{50} values of blackberry cultivars after laboratory freezing in January 1990 in Corvallis, Oregon.[z]

Hardiness divisions and cultivars	Pedigree	T_{50} Stem	T_{50} Bud	T_{50} Bud base
Benender	*R. trilobus* x *R. deliciosus*	-25	-19	-19
Black Satin	(US 1482 x Darrow) x Thronfree	-24	-20	-19
Smoothstem	US 1482 open pollinated	-23	-17	-19
Dirksen	(US 1482 x Darrow) x Thornfree	-22	-25	-26
Bailey	*R. allegheniensis* hybrid	-21	-15	-17
Womack	(F_2 of Brainerd x Brazos) x Brazos	-21	-17	-15
Darrow	(Eldorado x Brewer) x Hedrick	-21	-12	-13
Thornfree	(Brainerd x Merton Thornless) x (Mert. Thornless x Eld.)	-20	-22	-22
Eldorado	(*R. allegheniensis* x *R. argutus*) chance seedling	-19	-19	-22
Chester	SIUS 47 x Thornfree	-19	-19	-20
Comanche	Darrow x Brazos	-19	-17	-17
Austin	Self of Mayes open-pollinated	-18	-10	-10
Jenner	*R. ursinus* selection	-18	-17	-18
Merton Thornless	Spineless derivative of John Innes	-18	-13	-13
Hull Thornless	(US 1482 x Darrow) x Thornfree	-18	-18	-18
Cheyenne	Darrow x Brazos	-18	-18	-18
Cherokee	Darrow x Brazos	-17	-20	-20
Carolina	Austin Thornless x Lucretia	-17	-19	-20
Lucretia	*R. trivialis* selection	-17	-18	-18
Chehalem	Santiam x Himalaya	-17	-14	-17
Logan Thornless	Clonal selection of Logan	-17	-17	-17
Marion	Chehalem x Olallie	-17	-17	-15
Thornless Evergreen	*R. laciniatus* selection	-17	-13	-11
Snyder	*R. ursinus* selection	-16	-14	-14
Brazos	F_2 of (Lawton x Nessberry)	-16	-12	-12
Hillquist	*R. flagellaris* Willd. selection	-16	-14	-16
Cascade	Zielinski x Logan	-15	-14	-17
Kotata	(Pacific x Boysen) x (Jenner 1 x Eldorado)	-15	-17	-15
Olallie	Black Logan x Young	-14	-13	-16
Whitford	*R. flagellaris* Willd. selection	-14	-19	-22
Ebony King	Unknown	-14	-13	-15
Bedford Giant	Vetchberry self	-13	- 9	-13
Aurora	ORUS 616 x ORUS	-13	-14	-14
Young	Mayes x Phenomenal	-13	-13	-13
Boysen	Logan x *R. ursinus*	-13	-16	-17
Santiam	*R. ursinus* seleciton	-13	- 9	-13
Flordagrand	Regal Ness x *R. trivialis*	-13	-14	-14
Oklawaha	F_2 of Regal Ness x *R. trivialis*	-12	-14	-14
Anderson	Unknown	-11	-14	-15
Raven	Dewblack x Eldorado	-11	-15	-15
Zielinski	*R. ursinus* selection	-10	- 9	-10

[z]These values were calculated from 5 replicates treated at -5, -10, -15, -20, -25, -30, -35, -40C and a control stored at 4C.

raspberries. The T_{50} for the cultivar 'Darrow' was -21C, much less than previously reported by Moore and Brown (8) or Warmund et al. (14) in studies performed in Arkansas. The T_{50} of canes of 'Womack' was -21C. However, in February 1989, after an air temperature of -14C in the USDA-ARS NCGR field collection. 'Womack' was killed back to the ground (Hummer, personal observation). The mid-range blackberries included 'Comanche,' 'Cherokee' and 'Cheyenne' of the eastern erect-growing *R. allegheniensis* derivatives (Table 4). Warmund et al. (14) determined that these cultivars, which were released from Arkansas, survived below -23C. The hardening regime used in this study may have been insufficient to induce maximum cold hardiness for blackberries growing the Willamette Valley. Perhaps the lower temperature storage of -7C, as Warmund et al.(14) used in Missouri, achieved a lower mid-winter temperature in *Rubus* than did the -2C used in this study.

T_{50} values of 'Marion' and 'Thornless Evergreen' measured -17C after laboratory freezing (Table 4). Both are extensively planted in the Pacific Northwest. After experiencing -17C field conditions in the Willamette Valley in 1990, commercially produced 'Thornless Evergreen' showed far less injury than did 'Marion' (1).

In summary, most raspberries had lower T_{50} values than that of black raspberries or blackberries. Purple raspberries, were intermediate between red and black raspberries. Burnetholm and Canby red raspberries, and Brandywine and Royalty purple raspberries had the lowest T_{50} values. For some raspberry selections, the bud base was injured at the same or at a higher temperature that were the bud tissues inside the scales. Some hardy cultivars, such as 'Bristol' black raspberry produced offspring that had higher T_{50} values than those of the parent. T_{50} values for canes of most cultivars ranged from about 2 to 15C hardier than buds. Additional sources of hardy genes should be examined from wild germplasm, such as that in the Northern United States and Canada, to broaden the *Rubus* cold hardiness gene pool.

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