**USDA *Rubus* Crop Vulnerability Statement 2015**

**Summary**

Humans have been gathering and utilizing berries from various species of the highly diverse genus *Rubus* L. since the dawn of time. Although many plant parts of *Rubus* species have been used medicinally for thousands of years, berries were also gathered from wild stands for food. In the northern hemisphere, red raspberry (*R. idaeus* L.), cloudberry (*R. chamaemorus* L.), and arctic raspberry (*R. arcticus* L.) are gathered for commercial use from wild native stands; in Central and South America blackberries (primarily *R. glaucus*) are gathered for juice production. Improved raspberries and blackberries are cultivated crops grown for their commercial value.

Red raspberries, *Rubus idaeus* L., are the largest international commercially produced *Rubus* crop. In 2011, about 637,765 tonnes of raspberries were produced in about 48 countries. The US is the 4th largest producing nation with approximately 9% of the world’s crop. Raspberries rank as the third most popular berry in the United States for fresh consumption, after strawberries and blueberries. Washington State leads the US in processed red raspberry production. In 2010, Washington raised 61 million pounds of red raspberries valued at $50 million. Oregon leads the United States in black raspberry (*Rubus occidentalis* L.) production with 1.8 million pounds grown in 2011, valued at $2.3 million. California raised 81 million pounds of total raspberries valued at $200 million. Per capita consumption of fresh raspberries was 0.27 pound in 2008 with frozen raspberry consumption adding 0.36 pound.

Blackberry production is insufficiently large to be reported in the US Food and Agriculture Statistical Production Database. The majority of the world production is from the United States and Mexico, although other countries in Europe, South America, and Oceania are increasing acreage. In 2011, U.S. blackberry production was valued at $43.2 million, up from $30.8 million on 2009. Nearly all (90%) of blackberries are consumed in the form of frozen product/processed, given the delicate nature and limited shelf life of this large fresh fruit. Along with blueberries, boysenberries and tart cherries, blackberries have produced the largest increases in non-citrus crop value and grower prices in recent years. Fresh blackberry sales are increasing.

*Rubus* species have a complex genetic background including 2x-18x as well as aneuploid genomes. Centers for raspberry species diversity include Eurasia, Southeast Asia, Oceania, and North and South America. The primary cultivated gene pool of raspberries originates from the European *Rubus idaeus* and the American counterpart, *Rubus idaeus* ssp. *strigosus* and is diploid. Cultivars have been selected from the wild or developed through specific crosses within the last 450 years. The ploidy of blackberries varies from diploid through dodecaploid but most cultivars are 4x, or 6x-8x. Distribution of wild species is circumboreal.

The US national *Rubus* genebank is located at the US Department of Agriculture, Agricultural Research Service, National Clonal Germplasm Repository at Corvallis, Oregon. This facility maintains living collections of *Rubus* plants in containers under controlled growing environment as well as seed stored in freezers. The NCGR genebank collection includes more than 2,035 *Rubus* accessions, with representatives of 174 *Rubus* taxa from 57 countries. The primary collection of clonal *Rubus* and their wild relatives are maintained as plants in containers in greenhouses and screenhouses. More than 12,147 accessions have been distributed from the collection since 1981, when the genebank was established.

**Introduction: Botany and horticulture of *Rubus***

Plants of *Rubus* L., in the family *Rosaceae*, are known collectively as briars, brambles, caneberries, small, soft, bush, or berry fruits. Many people around the world consider plants of this genus to be roadside, invasive, or noxious weeds. Domestication, usually combined with breeding efforts, have developed several species of *Rubus,* or hybrids of multiple species, intoeconomically important cultivated fruit crops. This genus includes the cultivated red raspberries, blackberries, and their hybrids. In addition, fruit of native species such as cloudberries, arctic berries, Andean blackberries, and others are gathered from wild stands for consumption by local peoples. Fruits and plant parts of Asian species have been gathered for medicinal uses for millennia, although a taste for sweet berry fruit is a recent development. Breeders are continually searching for diverse species that might broaden the cultivated genepool.

In 20013, 578 thousand tonnes of raspberry (FAOSTAT, 2015) and more than 154 thousand tonnes of blackberry (Strik et al., 2007) were harvested worldwide with production expected to double in the next decade.

Throughout history, humans have interacted with thorny rambling and upright plants, such as raspberries and their relatives (Connolly, 1999). These plants were described by the ancient Greeks and Romans, including Aeschylus, Hippocrates, Cato the Elder, Ovid and Dioscorides (Hummer and Janick, 2007; Janick and Hummer, 2012; Hummer and Hall, 2013). The European blackberry and red raspberry initially documented by Ancient Greek and Roman rhyzomotists were illustrated on lost scrolls of western antiquity (Collins, 2000). These plants were considered medicinal with a wide range of pharmacological uses.

Raspberry seeds dating back to Roman times have been discovered in ancient forts in Britain. Roman soldiers probably spread the cultivation of red raspberries throughout Europe as they marched. Red raspberries were popularized and selected in Europe throughout the Middle Ages. Cultivation of the red raspberry began about this time in Europe. By the time of the Ancient Greeks, thornless forms were known and described (Hall et al. 2009, Hummer, 2010; Hummer and Janick, 2007).

In old English terms, raspberries were known as ‘hyndberries’, ‘raspis’ or ‘raspes’, giving rise to the modern term raspberry. Yellow-fruited forms, a colour mutant of the common red-fruited raspberry, were documented in Europe by the late 1500s. John Parkinson an English herbalist-botanist of that period described red, white and thornless raspis-berries suitable for the English climate (Jennings, 1988). Raspberries were grown for the London market by gardeners of Cheswick and Bretford in the time of Shakespeare (Jennings, 1988). Richard Weston, an English botanist, mentioned a ‘twice-bearing kind’ in 1780 (Jennings, 1988).

Europeans and Asians recognized the medicinal value of raspberries. The Asian raspberry, specifically *Rubus chingii* Hu, fu-pen-tzu, was documented in the *Ming I piehlu*, a Chinese herbal dating to the end of the Liang Dynasty before 300 ce (Hsu *et al*., 1986). Another Asian raspberry, *R. parvifolius* L., Tzu-po, is a traditional folk medicine of Taiwan (Hsu *et al*., 1986). The Indian medicinal uses of *Rubus* include application of the astringent diuretic action of the leaves and bark. Raspberry leaves are combined with many other herbs to produce ‘kasaya’.

The native *Rubus* species of Europe, such as the blackberry, *R. fruticosus*, and the red raspberry, *R. idaeus*, are not endemic in India but were brought there through human exchange from east to west along the Silk Route. Many web-related nutraceutical applications of Ayurvedic medicine promote the use of accessible European *Rubus* species, such as the red raspberries, *R. idaeus* L., rather than Asian ones, e.g., *R. coreanus, R. crataegifolius* or *R. parvifolius*. Raspberries were exported to the American colonies in the 1700s.

Probably one or more selections of the American red raspberry were cultivated in America by 1800 (Darrow, 1937). In 1771, W. Prince was the first to sell raspberry plants commercially in New York; his son W.R. Prince published a pomological manual in 1832 with descriptions of 20 cultivars (Jennings, 1988).

In 1853, the American Pomological Society recommended four European red raspberries for fruit cultivation, and by 1891, recommended 14 European and six American cultivars (Hedrick, 1925). The European raspberries proved less adaptable to the extremes of American summer and winter weather than did the local forms.

Improvements in red raspberries occurred when European red raspberries were crossed with American red raspberries (Jennings, 1988). Botanists have differed over whether or not American and European raspberries differ at the order of species or subspecies level. American native red raspberries differ from European ones by having hardier canes, which are thinner, taller, and more erect, and by the presence of glandular hairs. Fruit of American raspberries are usually round and seldom conical, and sometimes fruit in the wild are larger than that of the European subspecies (Jennings, 1988). The cultivar ‘Cuthbert’, most likely a cross between *R. idaeus* ‘Hudson River Antwerp’ and a native *R. strigosus*, was discovered about 1865. ‘Cuthbert’ remains a valuable cultivar and source of useful traits for present-day breeders. The present botanical terms recommend that these differences are at the species level (USDA, 2013).

**Biological features and ecogeographical distribution**

Raspberries are included within the genus *Rubus* L., under the family *Rosaceae* Juss. The plants within *Rubus* are diverse. Because of this, botanists have divided the genus into subgenera and sections. By morphological definition, raspberry fruits consist of clusters, or aggregates, of small drupe fruits called drupelets. The aggregate of drupelets are held together by interlocking hairs and the whole group of them separate as a unit (called an ‘aggregate fruit’) from a conical receptacle when the ripe fruit is picked.

Raspberries are placed in the tribe *Rubeae*. Some *Rubus* subgenera within this tribe (*Idaeobatus*, *Cylactis*, *Anoplobatus*, *Chamaemorus* and *Malachobatus*) have the raspberry-type fruit character, i.e. the aggregate fruit separates from the receptacle. Many raspberry-type species have contributed to the development of cultivated raspberry fruits (Table 1.1).

*Rubus* species cited as useful in raspberry and blackberry breeding programs throughout the world [modified from Daubeny (1996), Finn (2001), Finn et al. (2001), Finn and Knight (2002), Hummer et al. (2013) with additions].

|  |  |
| --- | --- |
| **Species** | **Traits of interest** |
| *R. arcticus* L. (and *R. stellatus*) | Earliness in primocane fruiting, good flavour, aroma, winter hardiness |
| *R. biflorus* Buch.-Ham. ex Sm. | Low chilling requirement, resistance to drought, tolerance to high temperature, leaf spot resistance, cane spot resistance |
| *R. argutus* Link | Excellent vigor and disease resistance. Primocane fruiting |
| *R. caucasicus* Focke | High fruit quality and yield, vigor, disease resistance, heat tolerance. |
| *R. chamaemorus* L. | High ascorbic acid content, winter hardiness |
| *R. chingii* Hu | Chinese traditional medicine |
| *R. cockburnianus* Hemsley | Very high numbers of fruits per lateral, late ripening |
| *R. corchorifolius* L. | Early ripening, erect habit |
| *R. coreanus* Miq. | Productivity, vigour, *Amphorophora idaei* and cane disease resistance, excellent black forms for crosses with black raspberry and yellow apricot forms for crosses with red raspberry |
| *R. crataegifolius* Bunge | Bright red fruit, easy plugging, pest and disease resistance, suitability for machine harvesting, early and condensed ripening |
| *R. flosculosus* Focke | Vigour, virus resistance, colour variations |
| *R. geoides* Sm. | Low-growing ornamental |
| *R. georgicus* Focke | Excellent vigor, excellent sweet flavor |
| *R. idaeus* (including *R. strigosus*) L. | Late fruiting season, resistance to root rot, vigour, winter hardiness, flavour, resistance to aphids, resistance to cane diseases, resistance to spider mites, ellagic acid content, resistance to viruses |
| *R. innominatus* Moore (including var. *kuntzeanus*) | Productivity, high fruit number/lateral, low chilling requirement, resistance to drought, high temperature, leaf spot, cane spot, cane beetle |
| *R. lasiocarpus* Focke | Disease resistance |
| *R. lasiostylus* Focke | Large fruit size, ease of harvest, fruit cohesiveness |
| *R. leucodermis* Doug ex Torrey & A. Gray | Vigour, disease tolerance, particularly viruses and verticillium |
| *R. mesogaeus* | Resistance to cane Botrytis, cane blight, cane midge |
| *R. multibracteatus* H. Lev. & Vaniot | Upright growth, bright red fruit |
| *R. niveus* Thunb. | Resistance to fruit rot, fruit quality, low chilling, fruit firmness, primocane fruiting |
| *R. occidentalis* L. | Phytophthora resistance, resistance to aphids, firmness, easy plugging, late ripening |
| *R. odoratus* L. | Earliness in primocane fruiting, ornamental potential, leaf and stem spot resistance, aphid resistance |
| *R. parviflorus* Nutt. | Resistance to root rot and aphids |
| *R. parvifolius* L. | Vigour, productivity, primocane fruiting |
| *R. phoenicolasius* Maxim. | Possible disease resistance, resistance to cane beetle, powdery mildew, root rot |
| *R. pileatus* Focke | Resistance to cane blight, cane midge, cane Botrytis, spur blight, fruit rot, root rot, fruit flavour |
| *R. pungens* Cambess. | Possible disease resistance, early ripening floricane fruit, winter hardiness, resistance to spur blight |
| *R. spectabilis* Pursh. | Earliness in summer and primocane types, bright red fruit, easy plugging, Phytophthora, cane Botrytis and Didymella applanata field resistance, resistance to aphids |
| *R. sumatranus* Miq. | High drupelet numbers |
| *R. ursinus* Cham. & Schltdl. | Very early ripening, excellent fruit quality. |

**Genetic base of crop production**

Until the 21st century, the main economic development in the commercial raspberry and blackberry occurred in subgenera *Idaeobatus* and *Rubus*, respectively. Additional subgenera have become increasingly important as parental contributors for the gene pool as breeding efforts search for useful and unusual traits.

*Idaeobatus* contains about 200 wild species. Most of these raspberry species are diploid, i.e., have two sets of chromosomes (2*n* = 2*x* = 14), but a few triploids (three sets of chromosomes) and tetraploids (four sets) have been documented (Thompson, 1995a, 1995b, 1997). *Idaeobatus* species are found in northern Asia, but are also located in Africa, Australia, Europe and North America (Jennings, 1988). The greatest diversity is found in southwest China, the likely centre of origin of the subgenus.

The subgenus *Rubus* contains about 200 wild species (GRIN, 2015) with a wide range of ploidy levels from 2x-18x and with many aneuploids (Thompson, 1995a, 1995b, 1997). While representatives of subgenus *Rubus* are found worldwide, the centers of origin for the cultivated species are in North America and Eurasia.

**Use of Primitive Forms**

Wild berries, such as those in genus *Rubus* have been collected throughout human history (Hummer and Janick, 2007). Humans have been gathering and utilizing berries from various species of the highly diverse since the dawn of time. Many plant parts of *Rubus* species were used medicinally for thousands of years. The fruit was also gathered from wild stands for food. In the northern hemisphere, red raspberry (*R. idaeus* L.), cloudberry (*R. chamaemorus* L.), and arctic raspberry (*R. arcticus* L.) are gathered for commercial use from wild native stands; in Central and South America blackberries (*R. glaucus*) are gathered for juice production.

Red raspberry, black raspberry, and blackberry value (US farmgate). While US statistics have been kept in California, Oregon and Washington and do represent the bulk of the value of Rubus production, a significant amount of blackberry acreage has been planted in the southeast US that is not captured in these figures.

**Domestic production and value; mean production per year over last 5 years (2009-2013).**



USDA, National Agricultural Statistics Service, *Noncitrus Fruits and Nuts*. 2015**.**

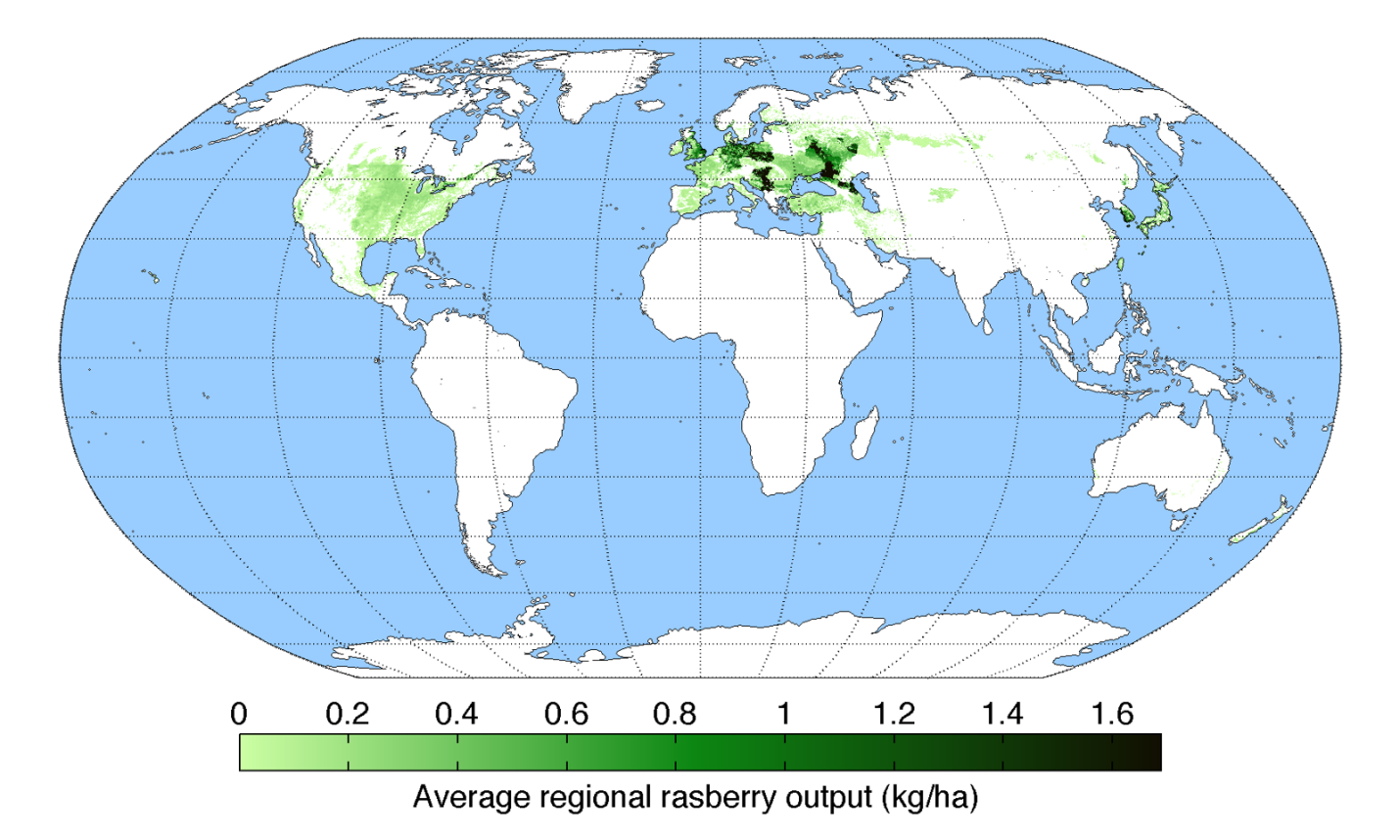
The United States had 538 farms certified for organic raspberry production. Total organic raspberry production was 4.7 million pounds. Berries were sold from 501 farms and were valued at $12.8 million (Organic Production Survey, 2008)

To meet consumer demand, the United States imports fresh raspberries. From November through May, most imports originate from Mexico. In 2010, the United States imported 13,927 metric tons (MT) of fresh Mexican raspberries valued at $118 million. During July and August, most fresh raspberries come from Canada. In 2010, the United States imported a total of 442 MT of Canadian raspberries valued at $658,000. Mexico is the world’s leading fresh market blackberry producer with about 115,000 tonnes exported from 16,000 ha predominantly to the US between October and May every year. While the US leads the world in processed blackberry production, Serbia is also a major producer with about 12,500 ha.

**International production**

In 2011, about 637,765 tonnes of raspberries, (*Rubus idaeus* L.), were produced in about 48 countries. The US is the 4th largest producing nation with approximately 9% of the world’s crop.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Country** | **2010** | | **2011** | |
| Russia | 125,000 | 27% | 140,000 | 26% |
| Poland | 92,864 | 20% | 117,995 | 22% |
| Serbia | 83,870 | 18% | 89,602 | 16% |
| United States | 36,741 | 8% | 48,948 | 9% |
| Ukraine | 25,700 | 5% | 28,100 | 5% |
| Mexico | 14,343 | 3% | 21,468 | 4% |
| United Kingdom | 17,000 | 4% | 16,761 | 3% |
| Canada | 11,864 | 3% | 12,285 | 2% |
| Azerbaijan | 10,100 | 2% | 11,000 | 2% |
| Spain | 9,226 | 2% | 9,559 | 2% |
| Source: UN FAOSTAT (2013) | | | | |



<http://faostat.fao.org/site/567/default.aspx#ancor>. Accessed 7 May 2013.

The US is the leading producing nation with approximately 28% of the world’s crop, followed by Spain, Turkey, Mexico, Egypt, Russian Federation, Japan, Republic of Korea, and Poland. The industries in the US, Spain, and Mexico have grown over the last decade while production in Japan, Italy, and Poland has declined to report.

**2. Urgency and extent of crop vulnerabilities and threats to food security**

*Rubus* species tend to be robust plants with vigorous growth where endemic. Many species are vigorous to the point of being intrusive. Some blackberry species are considered to be alien invaders where introduced into favorable climates. Several species of European *Rubus* (*R. moluccanus* L. and *R. fruticosus* aggr. (which includes such species as *R. armeniacus* Focke*,* *R. laciniatus* Willd.). Appear on the US Noxious Weed list.

Four *Rubus* species have status on the International Union for Conservation of Nature (IUCN, 2015) Red list of endangered species.

International Union for Conservation of Nature (IUCN) Red List of endangered *Rubus* species

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Species** | **Country** | **Status** | **Year designated** | **Threat** |
| *R. azuayensis* Romoleroux | Ecuador (Andes) | Vulnerable | 2004 | Pollution |
| *R. laegaardii* Romoleroux | Ecuador (Andes) | Vulnerable | 2004 | Pollution |
| *R. takhtadjanii* Mulk. | Armenia | Critically endangered | 2007 | Human encroachment |
| *R. zangezurus* Mulk. | Armenia | Critically endangered | 2007 | Human encroachment |

**Food Security**

Of the seven major classes of human nutrients, the berry crops, such as *Rubus*, provide carbohydrates, fiber, minerals, vitamins, and water. *Rubus* fruits contain many metabolites that strongly impact consumer’s senses and health. Most analytical biochemical studies of berry fruits have relied on specific extraction/separation methods to identify and quantify targeted compounds and interests.

Fruit firmness and drupelet skin toughness are genetically complex traits that have been a focal point of large breeding programs during the past 50 years. The increase in these traits provided through breeding has provided the blackberry and raspberry industries with the capability to move fresh fruit to the far reaches of the globe and allowed for mechanical harvesting.

Rubus berries are rich in vitamin C (ascorbic acid), ellagic acid, and other phenolic compounds (Moyer et al., 2002a; 2002b). These compounds have a significant role in promoting human health. The amount of phenolic compounds varies between cultivars and between different plant parts at different levels of ripeness.

**2.1 Genetic uniformity in the “standing crops” and varietal life spans**

*Rubus* species are predominantly out-crossing and highly diverse. However, several blackberry species are partially to fully apomictic. The distribution of this genus ranges on 6 of the 7 continents from > 4,250 meters (14,000 feet) to sea level. The morphology is highly diverse.

Nondisjunction, interspecific hybridization, apomixis alone, and in combination with hybridization, provides challenges to *Rubus* taxonomy (Hummer et al., 2015). The natural formation of facultatively pseudogamous apomicts via allopolyploidization frequently occurs in this genus (Jennings, 1988).



*Rubus* leaf diversity. Photo by Joseph Postman, USDA ARS.

**Varietal life spans**

Most cultivated *Rubus* germplasm is not far removed from wild relatives and new germplasm can be introgressed and developed into cultivars in as little as one generation as is the case with something like 'Wild Treasure' (Finn et al., 2010) but is more likely to take 2-4 generations of crossing between the species derivative and improved germplasm before cultivar quality material is obtained. Obviously, this is much longer than what is expected from elite-by-elite crosses. Most breeding programs work under long-term objectives, preparing multiple penultimate releases from advanced breeding lines without returning to the incorporation of new wild germplasm. Frequently one breeder will make a cross and his/her successor will evaluate and make the final release. Sometimes breeding programs will share advanced lines with the consideration of mutual benefit when a selection is successful. In some cases, germplasm enhancers work with wild material and breed and select for “germplasm releases,” after which breeders work from that release to develop advanced lines and cultivars.

Some cultivars never become widely adopted, and a few years after release and are essentially “lost” from production nursery lists. Others survive 40 or 60 years. In the private sector, the life span of a successful cultivar is no longer than the length of a US plant patent, which is 20 years. The ratio of successful releases to total releases seems to be about 1/5 for per breeding program. Some older cultivars are tried in another geographic or climatic niche and then have a renewed life span of several decades. The following table includes some examples of “life spans” for a few publicly available *Rubus* cultivars (M. Dossett, personal communication).

|  |  |  |
| --- | --- | --- |
| **Cultivar** | **Life Span** | **Location Released** |
| Red raspberry |  |  |
| Boyne | 1960 – still grown but very limited acreage | Manitoba |
| Canby | 1953- current | Oregon |
| Chilliwack | 1987-still grown but very limited acreage | British Columbia |
| Cuthbert | 1865-still very popular in 1925 | New York |
| Dormanred | 1972- current but small and not really a red raspberry; grown in low chill areas | Mississippi |
| Fallgold | 1967 – currently in production | New Hampshire |
| Goldenwest | 1953 – currently in production | Washington |
| Heritage | 1969 – current | New York |
| Mandarin | 1955 – current but small, for the Southern States of the United States | North Carolina |
| Meeker | 1967 – current | Washington |
| Tulameen | 1989 – current | British Columbia |
| Willamette | 1944 – current especially in Serbia | Oregon |
| Blackberry |  |  |
| Chester Thornless | 1985 – current | Maryland |
| Marion | 1956 – current particularly in Oregon | Oregon |
| Olallie | 1944 – present, small acreage in California | Oregon |
| Thornfree | 1966 – present, particularly popular in Serbia | Maryland |
| Black raspberry |  |  |
| Jewel | 1973 – currently in production | New York |
| Munger | 1897 – currently in production | Ohio |

**Biotechnology in *Rubus* breeding**

The potential for positive application of biotechnology to *Rubus* is tremendous but faces challenges including some who are ideologically opposed to the use of genetic engineering in breeding as well as the high cost of research, development and regulatory approval. A more likely use of biotechnology is the use of molecular markers that are in development or in early stages of utilization to improve the efficiency of breeding programs.

Some traits that would seem to be particularly of interest for utilization of molecular markers or genetic engineering might include:

* Disease, i.e., *Raspberry bushy dwarf virus*, *Phytophthora* root rot) and pest resistances (research has been done in this area.)
* Enhanced flowering and fruiting (primocane fruiting)
* Fruit quality, particularly sweetness and or firmness/skin toughness

Fruit tolerance of UV light/heat

Diseases of *Rubus* species. X = laboratory detection; (X) = visual detection for certification**.**

|  |  |
| --- | --- |
| Disease agent | Raspberry, blackberry, and species |
| apple mosaic virus | X |
| arabis mosaic virus | X |
| beet pseudo-yellows virus | X |
| black raspberry necrosis virus | X |
| blackberry chlorotic ringspot virus | X |
| blackberry leaf mottle associated virus | X |
| blackberry vein banding associated virus | X |
| blackberry virus E | X |
| blackberry virus S | X |
| blackberry virus Y | X |
| blackberry yellow vein associated virus | X |
| *Cercosporella rubi* | (X) |
| cherry leaf roll virus | X |
| cherry rasp leaf virus | X |
| cucumber mosaic virus | X |
| *Didymella applanata* | (X) |
| *Erwinia amylovora* | *X* |
| grapevine Syrah virus 1 | X |
| *Gymnoconia peckiana* | (X) |
| impatiens necrotic spot virus | X |
| *Phytophthora rubi* | X |
| raspberry bushy dwarf virus | X |
| raspberry latent virus | X |
| raspberry leaf blotch virus | X |
| raspberry leaf mottle virus | X |
| raspberry ringspot virus | X |
| raspberry vein chlorosis virus | X |
| *Resseliella theobaldi* | (X) |
| *Rhodococcus fascians* | (X) |
| rubus canadensis virus-1 | X |
| *Rubus stunt phytoplasma* | X |
| rubus yellow net virus | X |
| sowbane mosaic virus | X |
| strawberry latent ringspot virus | X |
| strawberry necrotic shock virus | X |
| tobacco ringspot virus | X |
| tobacco streak virus | X |
| tomato black ring virus | X |
| tomato ringspot virus | X |
| *Verticillium albo-atrum* | X |
| *Verticillium dahliae* | X |
| *Xylella fastidiosa* | *X* |

**Biotic**

**Viruses**

Virus diseases are very important in *Rubus*, motivating extensive testing and certification programs in the nursery industry. Martin et al. (2004, 2013) has recommended procedures for detection of *Rubus* viruses. These tests include bioassays on indicator plants, sap and graft inoculation, enzyme linked immunosorbent assay, double-stranded RNA isolation, polymerase chain reaction (PCR) and as of 2015 large scale sequencing (Gergerich et al., 2015).

Plant material should be obtained from sources with the lowest risk of virus infection, derived from pathogen-tested sources. Frequently, this is not possible in germplasm exploration or exchange activities, particularly if plant material is collected from the wild, or the source has no resources for pathogen testing. If certified germplasm, free of targeted pathogens is unavailable, the germplasm should be obtained and subjected to elimination procedures upon arrival at the recipient country. Virus elimination techniques are described by Diekmann et al. (1994) and Wang et al. (2009).

Clonal virus-tested collections should be protected from access by virus vectors, i.e., aphids. New plant accessions should be grown in a location isolated from the foundation collection and fumigated or observed to prevent the introduction of exotic insects or diseases into the protected collection.

In the US, the National Clean Plant Network (NCPN) is a consortium of effort between the Animal and Plant Health Inspection Service (APHIS), the Agricultural Research Service, and the Research, Education, and Extension (university branch) (Gergerich et al., 2015). NCPN has facilities in the eastern and western US that provide pathogen negative foundation level clean stock to nursery growers.

Need to add text still with specific information regarding threats of particular viruses – RBDV, RMLV, RpLV, RYNV, BRNV in raspberry. Others in blackberry…

**Fungal and bacterial diseases**

Fruit rots cause extensive losses to caneberry growers each year. Development of cultivars with increased resistance to pre- and post-harvest fruit rot diseases should result in reduced use of fungicides and greater profits for growers. Kidd et al. (2004) evaluated blackberry cultivars and breeding selections developed in Arkansas for post-harvest fruit rot resistance and reported a wide range of post-harvest fruit rot responses among them. Among 20 cultivars in their trial, ‘Kiowa’ ‘Navaho’, and ‘Triple Crown’ had the fewest berries with post-harvest diseases symptoms and the lowest total disease scores. *Botrytis cinerea* as well as other emerging botrytis speciesare the most important post-harvest pathogens with fungicide resistant isolates discovered continually (Li et al., 2012; Grabke et al., 2014) whereas *Colletotrichum* spp. was found much less frequently. ‘Kiowa’, ‘Ouachita’, ‘Navaho’, ‘Chester’, ‘Triple Crown’, ‘Apache’, and ‘Arapaho’ berries were the firmest among the cultivars in their trials. The authors concluded that substantial fruit rot resistance existed among genotypes and variation for resistance could be used in breeding. They also indicated that breeding for Botrytis fruit rot resistance was an important objective in the Arkansas blackberry breeding program.

Fruit rots are also extremely important in raspberry. While there is some innate resistance to *Botrytis* and/or *Rhizopus* fruit rotsin ‘Cuthbert’, ‘Matsqui’, ‘Meeker’, ‘Nootka’ and ‘Vene’, most *R. idaeus* and *R. strigosus* germplasm has poor shelf life and is quite susceptible to fruit rots. Jennings and Carmichael (1975) showed that large improvements could be made from the use of *Rubus occidentalis* germplasm, presumeably related to its firmness. Subsequent work has shown that some of the Asian *Rubus* species, in particular *R. pileatus*, are also particularly valuable in this regard (Hall and Brewer, 1993; Stephens et al., 2002).

Rosette disease caused by *Cercosporella rubi* is also a limiting factor in blackberry production in the southern United States (Smith and Fox, 1991). Lipe (1986) reported that ‘Humble’ was immune to rosette while ‘Brazos’ and ‘Rosborough’ were tolerant. However, Buckley et al. (1995) considered ‘Humble’ to be a resistant but not immune cultivar. Gupton and Smith (1997) reported that the mean rosette severity ratings of progeny from crosses among seven cultivars including ‘Humble’, ‘Brazos’, and ‘Rosborough’ were always intermediate between those of the parent cultivars. Jennings (1988) also reports that *R. armeniacus* is immune. ‘Navaho’, ‘Ouachita’, and ‘Chickasaw’ had the fewest berries with post-harvest disease symptoms, while ‘Shawnee’ and ‘Arapaho’ had the highest *Botrytis* fruit rot scores (Smith and Miller-Butler, 2016). Cultivars with the lowest levels of post-harvest fruit diseases received good quality evaluations. The erect, thorny cultivars, ‘Chickasaw’, ‘Shawnee’, and ‘Kiowa’, had significantly more rosettes per plant than the thornless cultivars, ‘Sweetie Pie’, ‘Navaho’, and ‘Apache’.

*Xyllela fastidiosa* is becoming more of an issue in the southern latitudes as strains able to infect new hosts are continually identified (Nunney et al., 2014). *Erwinia amylovora*, the causal agent of fire blight, is also becoming a pathogen of concern (Powney et al., 2011), especially in areas with wet and cool springs allowing for the disseminiation of the bacterium by pollinating insects. Although the strains that infect caneberries do not appear pathogenic to pome fruit and vice versa, its devastating effects on caneberries, in conjunction with the fact that only a few caneberry cultivars have been screened for resistance to the pathogen (Bastas and Sahin, 2014), brings the bacterium to the forefront when it comes to crop sustainability.

Phytophthora root rot

Verticillium

**Insect and arthropod pests**

*Aphids*

**The North American raspberry aphid,** Amphorophora agathonica **Hottes, is the principal vector for four viruses in the** Raspberry mosaic virus **complex which contribute to field decline and crumbly fruit symptoms in red raspberries and for *Black raspberry necrosis virus* in black raspberries in the Pacific Northwest (Halgren et al., 2007).  Breeding for aphid resistance in red raspberry has been a major emphasis in raspberry breeding in British Columbia since the 1960s. The most widely used resistance gene in the breeding program,** Ag**1**, **broke down in 1990. The appearance of additional resistance-breaking aphid biotypes since then has resulted in the need to identify new sources of resistance and develop approaches for maintaining their durability. Several sources of resistance in wild red and black raspberry germplasm have been identified and current efforts are aimed at identifying genetic markers for unbroken resistance sources to aid in effectively pyramiding resistance genes to slow the breakdown of resistance (Bushakra et al., 2015; Dossett and Kempler, 2015).**

*Spotted-wing Drosophila*

Spotted-wing Drosophila (SWD), *Drosophila suzukii* Matsumura*,* is a recently introduced exotic insect pest in the Americas (Lee et al., 2011) and Europe. Populations of SWD in the Western Hemisphere originated somewhere in Asia, possibly Korea, Japan, China, Southeast Asia, Sri Lanka or India (Markow and O’Grady, 2006). The highly invasive SWD spread globally from Asia to Europe and North America and, in 2008, became a major pest of US fruit crops.

*Nematodes*

In addition to the potential virus problems spread by *Longidorus* and *Xiphinema* sp., root lesion nematodes (*Pratylenchus* sp.) are a production-limiting problem in many raspberry production areas, and root-knot nematodes (*Meloidagne* sp.) can also be problematic. At present, pre-plant fumigation and periodic application of systemic nematicides are the only treatment, but are not always efficacious, and increased regulatory burdens are limiting their useage. Vrain and Daubeny (1986) identified some resistance to *Pratylenchus penetrans* in wild *R. strigosus* germplasm as well as a hybrid with *R. crataegifolius*. More recently, Zasada and Moore (2014) surveyed a number of *Rubus* species and found *R. leucodermis* and *R. niveus* to be consistently poor hosts for *P. penetrans*, but noted that a hybrid between *R. niveus* and ‘Tulameen’ did not consistently support fewer nematodes than the susceptible ‘Meeker’ control.

*Mites*

The recent increase in sprays to control Spotted-winged Drosophila, have led to a marked reductions in mite predators in commercial raspberry fields and a corresponding increase in mite damage and the frequency of flare ups. Two-spotted spider mite (*Tetranychus urticae* Koch), is the most common mite causing damage in commercial raspberry fields. The problem is exacerbated in hot dry seasons and climates, as well as in protected cultivation, such as high tunnels. There is genetic variation for susceptibility to two-spotted spider mite (Wilde et al., 1991), but this is an area which needs further study.

**Accessibility (inability to gain access to needed plant genetic resources because of phytosanitary/quarantine issues, inadequate budgets, management capacities or legal restrictions)**

Since the implementation of the International Treaty for Plant Genetic Resources for Food and Agriculture in 2004, participant countries use agreements for plant exchange. Some countries have restrictive requirements for tracing all future distribution of their plant material. Other countries cannot meet demands for this requirement. Lack of mutual agreement has precluded formal governmental plant exchange of *Rubus* germplasm from some countries (such as China and several from Central and South America) into the US during this time.

**Status of plant genetic resources in the NPGS available for reducing genetic vulnerabilities**

The US National *Rubus* genebank collection is kept *ex situ* at the US Department of Agriculture, Agricultural Research Service, National Clonal Germplasm Repository in Corvallis, Oregon. Primary collections of living plants are maintained in containers in controlled environments such as screenhouses and greenhouses. Backup onsite redundancy includes the core collection being preserved as tissue cultures. Back-up seed of species have been sent to the USDA, ARS National Center for Genetic Resource Preservation in Ft. Collins, Colorado, and to Svalbard Global Seed Vault in Svalbard, Norway.

**Germplasm collections and in situ reserves**

The NCGR genebank collection includes 174 *Rubus* species (Appendix Table 1) and about 2,020 accessions. The NCGR genebank includes a primary collection of living plants, protected in containers in greenhouses and screenhouses. Aphids, which vector viruses, are excluded from these houses. Integrated pest management techniques minimize powdery mildew, spider mites and other key pests. A core collection representing world species and heritage cultivars has been defined. A secondary backup core collection is maintained *in vitro* under refrigerated temperatures. A long-term backup core collection of meristems has been placed in cryogenic storage on site, and at the remote base location, National Center for Genetic Resource Preservation, Ft. Collins, Colorado.

At Corvallis, species diversity is represented by seed lots stored in -18 C. In addition, living plant representatives of major taxa are maintained in pots in screenhouses. Plants are tested for common viruses, viroids, and phytoplasmas as funding allows. Plant identity is checked by comparison with written description, review by botanical and horticultural taxonomic experts, and evaluation by molecular markers, such as simple sequence repeat markers. SNP markers and genotyping by sequencing (GbS) approaches are under development.

The collection has been documented for accession, inventory, voucher images and morphological and genetic observations on the Germplasm Resources Information Network (GRIN) in Beltsville, Maryland.

The collection presently includes about 320 cultivars. Other major cultivars from the US or Europe not in the collection are being sought to broaden representation of historical cultivars. Species representatives could be obtained from Alaska, Hawaii, Western and Southwestern United States (including Oregon, Montana, Utah, Arizona, New Mexico), across Canada, from Chile, Ecuador, Peru, China, Korea, India, Bhutan, Russia (Kurile Islands, Kamchatka, Amur) Japan, India, Nepal, and Oceania, including the Southeastern Pacific islands such as Malaysia, along with New Zealand and Australia.

Although *Rubus* has high diversity in subtropical areas, these species are suited to warm climates. Protected cultivation is required for the the germplasm to be maintained in temperate Corvallis, Oregon, where the genebank is located. However, with many more countries interpreting the rules of international treaties concerning accessibility to plant genetic resources to increase restrictions, it is wise for explorations to proceed where permission is granted. The genebank should be “ahead” of and anticipating breeder needs.

*In situ* reserve agreements have not been established in the United States for *Rubus*. This genus would be a good candidate to consider in situ conservation within the United States.

**Holdings**

The NCGR-Corvallis holdings include two types of accessions: clonal and species

1) Clonal plants (living collections) that are propagated vegetatively and represent specific genotypes. These include heritage cultivars, newer cultivars, selections which contain specific traits of interest and elite wild accessions.

2) Broader species collections are represented by seed lots or additionally by plant representatives of certain populations.

The available *Rubus* clonal collection at the NCGR-Corvallis is listed in Appendix Table 3. Real time lists can be obtained by searching GRIN accession text query entering: “*Rubus* cultivar”.

The *Rubus* species collection at the NCGR-Corvallis is listed in Appendix Table 1.

**Genetic coverage and gaps**

**Clonal holdings**

The collection presently has about 500 heritage cultivars. Other major heritage cultivars from the US or Europe not in the collection are being sought to broaden representation of historical cultivars.

A list of heritage cultivars that the Repository would like to obtain includes:

Red Raspberry

August Red

John Innes

Norwich Wonder

November Abundance

Novost Kuzmina

October Red

Park Lane

Pyne’s Royal

Perfection

Red Antwerp

Red Cross

St. Walfred

Blackberry?

Not sure I can think of any

Black raspberry

Bristol

Blackhawk

New Logan

Plum Farmer

Shuttleworth

Allen

**Domestic collection gaps**

* Northern reaches in Alaska; Unalaska and Archipelago
* Southwestern United States below Colorado.
* *Rubus strigosus* from the eastern US.

**List of designates primary, secondary, and tertiary crop wild relatives**

**Primary genetic relative:** *taxa that cross readily with the crop (or can be predicted to do so based on their taxonomic or phylogenetic relationships), yielding (or being expected to yield) fertile hybrids with good chromosome pairing, making gene transfer through hybridization simple.*

1. Rubus allegheniensis ( [39 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20allegheniensis))
2. Rubus canadensis ( [15 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20canadensis))
3. Rubus chingii ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20chingii))
4. Rubus cuneifolius ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20cuneifolius))
5. Rubus flagellaris ( [12 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20flagellaris))
6. Rubus floribundus ( [9 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20floribundus))
7. Rubus glaucus ( [30 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20glaucus))
8. Rubus idaeus subsp. idaeus ( [365 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20idaeus%20subsp.%20idaeus))
9. Rubus idaeus subsp. strigosus ( [119 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20idaeus%20subsp.%20strigosus))
10. Rubus innominatus ( [6 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20innominatus))
11. Rubus laciniatus ( [10 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20laciniatus))
12. Rubus leucodermis ( [50 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20leucodermis))
13. Rubus occidentalis ( [227 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20occidentalis))
14. Rubus parvifolius ( [36 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20parvifolius))
15. Rubus pensilvanicus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pensilvanicus))
16. Rubus sachalinensis ( [49 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20sachalinensis))
17. Rubus trivialis ( [25 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20trivialis))
18. Rubus ursinus ( [83 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ursinus))
19. Rubus ursinus subsp. macropetalus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ursinus%20subsp.%20macropetalus))

**Secondary genetic relative*:*** *taxa that will successfully cross with the crop (or can be predicted to do so based on their taxonomic or phylogenetic relationships), but yield (or would be expected to yield) partially or mostly sterile hybrids with poor chromosome pairing, making gene transfer through hybridization difficult.*

1. Rubus arcticus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20arcticus))
2. Rubus arcticus nothosubsp. stellarcticus ( [6 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20arcticus%20nothosubsp.%20stellarcticus))
3. Rubus arcticus subsp. arcticus ( [7 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20arcticus%20subsp.%20arcticus))
4. Rubus arcticus subsp. stellatus ( [6 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20arcticus%20subsp.%20stellatus))
5. Rubus chamaemorus ( [29 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20chamaemorus))
6. Rubus chingii ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20chingii))
7. Rubus corchorifolius ( [7 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20corchorifolius))
8. Rubus coreanus ( [10 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20coreanus))
9. Rubus crataegifolius ( [17 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20crataegifolius))
10. Rubus cuneifolius ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20cuneifolius))
11. Rubus deliciosus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20deliciosus))
12. Rubus ellipticus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ellipticus))
13. Rubus eustephanos ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20eustephanos))
14. Rubus flagellaris ( [12 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20flagellaris))
15. Rubus floribundus ( [9 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20floribundus))
16. Rubus formosensis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20formosensis))
17. Rubus fruticosus aggr. ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20fruticosus%20aggr.))
18. Rubus glaucus ( [30 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20glaucus))
19. Rubus illecebrosus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20illecebrosus))
20. Rubus inermis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20inermis))
21. Rubus laciniatus ( [10 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20laciniatus))
22. Rubus lasiostylus
23. Rubus macilentus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20macilentus))
24. Rubus macvaughianus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20macvaughianus))
25. Rubus mesogaeus ( [5 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20mesogaeus))
26. Rubus xneglectus ( [15 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20neglectus))
27. Rubus nepalensis ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20nepalensis))
28. Rubus nivalis ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20nivalis))
29. Rubus niveus ( [17 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20niveus))
30. Rubus nubigenus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20nubigenus))
31. Rubus odoratus ( [11 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20odoratus))
32. Rubus palmatus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20palmatus))
33. Rubus palmatus var. coptophyllus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20palmatus%20var.%20coptophyllus))
34. Rubus parviflorus ( [32 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20parviflorus))
35. Rubus parvifolius ( [36 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20parvifolius))
36. Rubus pensilvanicus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pensilvanicus))
37. Rubus phoenicolasius ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20phoenicolasius))
38. Rubus plicatus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20plicatus))
39. Rubus sanctus ( [8 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20sanctus))
40. Rubus saxatilis ( [8 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20saxatilis))
41. Rubus spectabilis
42. Rubus trifidus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20trifidus))
43. Rubus trivialis ( [25 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20trivialis))
44. Rubus ursinus ( [83 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ursinus))
45. Rubus ursinus subsp. macropetalus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ursinus%20subsp.%20macropetalus))
46. Rubus urticifolius ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20urticifolius))

**Tertiary genetic relative:** *taxa that can be crossed with the crop (or can be predicted to do so based on their taxonomic or phylogenetic relationships), but hybrids are (or are expected to be) lethal or completely sterile. Special breeding techniques, some yet to be developed, are required for gene transfer.*

See the list of taxa in Appendix Table 1. *Rubus* species have multiple ploidy levels. Crosses between species at differing ploidy levels are common in nature and by breeders.

**Gaps in foreign species holdings**

Species representatives are especially needed from Alaska, Hawaii, Western and Southwestern United States, across Canada, from Chile, Ecuador, Peru, China, Korea, India, Bhutan, Russia (Far Eastern Territories including: Kurile Islands, Kamchatka, Amur) Japan, India, and Nepal. *Rubus* needs to be collected across Canada. Particular attention should be given to Northwestern and Northeastern Canada.

**Acquisitions**

**Plants**

*Rubus* plants or plant parts from foreign countries are restricted entry unless a valid post entry import permit is present. The curator must obtain and maintain a valid USDA post entry import permit to receive *Rubus* plants or plant parts from outside the US.

Permits can be obtained through application the USDA APHIS PPQ website

<http://www.aphis.usda.gov/plant_health/permits/>

APHIS works with the Oregon Department of Agriculture (ODA) to provide inspection of plant material for the Rubus stored at the National Clonal Germplasm Repository at Corvallis, Oregon.

**Seeds**

Seeds are extracted from dried fruits. To extract the seeds, the fruit are soaked in xx% solution of pectinase overnight. The solution is put in a blender with the blades masked. The solution and the fruit pulp are decanted. Floating seeds are eliminated. The seeds that sink are air dried on paper towels and then dried in desiccators to about 6 % moisture. Seeds are germinated and plant representatives are chosen from vigorous seedlings.

**Seed germination**

Many blackberry and raspberry seed exhibit delayed or poor germination because of a deep double dormancy (Hummer and Peacock, 1994; Peacock and Hummer, 1994), and there is evidence that cultivated germplasm has been selected for genotypes that respond to specific germination protocols that may yield poor results for wild-collected seed (M. Dossett, pers. Obs, manuscript in preparation). Only four of 17 species had ≥ 50% germination of immediately-germinated, non-scarified seed, indicating primary seed dormancy (Wada and Reed, 2011a; 2011b). Seed-coat thickness was better correlated with seed size (R = 0.82) than was hardness (R = 0.71). Dry seed of three species each in the subg. Idaeobatus and Rubus were scarified with concentrated sulfuric acid (98% H2SO4) or sodium hypochlorite (14% NaOCl) followed by germination treatments of deionized water (DI), smoke gas solution, gibberellic acid (2.03 mg/L GA3) with potassium nitrate (34 mg/L KNO3) or GA3 alone. Germination after H2SO4 scarification was significantly better than NaOCl for four of the six species despite equal reduction in the seed coat by the scarification treatments. H2SO4-scarified seed had maximum germination in 6–8 months compared to 12 months for NaOCl-scarified seed. Scarification treatments were not uniform for the subgenera. Increased H2SO4 scarification durations monitored by viability testing with 2,3,5 triphenyl tetrazolium chloride (TZ) were effective in determining optimal scarification timing. *Rubus georgicus* and *R. occidentalis* H2SO4-scarified seed treated withGA3 +KNO3 or smoke germinated significantly better than the other treatments; GA3 +KNO3, smoke and DI water were equally effective for the other four species.

H2SO4 scarification followed by a treatment with KNO3 and GA3 during stratification was highly effective for the most species. However, the commonly used scarification protocols were ineffective for some species. Effective scarification exposure was established based on the amount of embryo damage seen with 2,3,5 triphenyl tetrazolium chloride (TZ) viability testing. Two species in subgenus Anoplobatus had a hilar-end hole that allowed rapid germination of unscarified seed. Some species with extremely hard seed coats had little or no germination, and longer scarification times are needed. Seed size, seed-coat thickness and morphology can determine seed cultivar identity (Wada et al., 2011).

Nesme (1985) demonstrated that in addition to the physical limitations of the endocarp, dormancy factors seem to be located in the testa and endosperm, as raspberry embryos with the endocarp damaged and an intact testa and endosperm did not germinate whereas 100% germination was obtained within 15 days if the endocarp, testa and endosperm were all removed. This, in combination with the previously studies highlighting the difficulty of seed germination, suggests that despite it being a labor-intensive process, in-vitro seed germination protocols that include the complete removal of seed coats are likely to result in the highest germination rates of *Rubus* germplasm.

**Clonal storage**

**Greenhouses**

The greenhouses are used for plant propagation, virus testing and elimination, overwintering tender plants, flower forcing for identification or seed production, and short-term research projects. Permanent plant collections are not generally kept in the greenhouses, however, post-entry quarantined plants, special permit plants, and some virus collections are kept in Greenhouse 4.

**Greenhouse Assignments**

Greenhouse 1 This house is the main propagation house and is heated or cooled all year and equipped with grow lights. Half of the benches have bottom heat. The first four benches are mist beds with biotherm bottom heat for rooting cuttings and acclimatization of in-vitro cultured plants. Benches are available for seedling production, propagation for screenhouse and field collections, plant requests, research projects, plant reserves for IPM projects, and virus indicator plant propagation.

Greenhouse 2 This house is usually not heated in winter. Grow lights are available over some benches. This house is mainly used for hardening off plants for screenhouse and field collections, overwintering of non-hardy collections, grafting and layering of *Pyrus*, *Corylus*, and other miscellaneous genera.

Greenhouse 3 This house is used for virus testing and elimination, and other plant pathology related projects. It contains two growth chambers and a small mist bed and is usually not heated in winter.

Greenhouse 4 This house is divided into 6 sections by insect proof screen walls, and is used to house post-entry quarantine plants. It is not heated in the winter to accommodate the chilling requirements of these plants. A heat mat in section 5 can be used to provide bottom heat to a small number of plants. Section 5 is used as an isolation room and spray room to sanitize plants arriving at the facility, or moving between repository locations. Section 6 contains a collection of germplasm borne pathogens as infected plants.

**Plant movement**

* All plants moving into any greenhouse from the field, shadetube, screenhouse, or from outside the repository must first enter the pest treatment room for inspection and pest elimination.
* Plants should not be removed from the treatment room until they have been examined\treated for pests.
* Bench space should be requested from the greenhouse manager who will assign space and provide a bench label.
* Plants are not to be moved from bench to bench or house to house without the permission of the greenhouse manager or person responsible for those plants.
* Doors must be kept closed whenever possible to minimize the immigration and spread of pests into and between the greenhouses.

**Cultural practices**

In general, all plants in the greenhouse will be subject to the following cultural practices to aid in pest management and genetic integrity.

1. Flowers and fruit will be removed.

2. Excess foliage will be pruned.

3. Plants on benches will be at least 1 pot distance apart.

4. Dead plants will be removed as soon as possible.

5. Plants will be properly labeled with both plant name and local number.

6. Soil stored outside will be pasteurized at 160oF for 1 hour before use.

7. Weeds will be removed from pots, from beneath benches, and from areas immediately outside of the greenhouses.

8. Pots, bamboo stakes, etc. will be sanitized between uses.

**Freezing weather preparations**

1. Turn on the heating water supply valve slightly in greenhouses 2, 3 and 4 to keep water circulating in the pipes and prevent freezing and breakage. Valves are located above the north door inside each greenhouse.

2. Check that the water supply to the swamp coolers in all greenhouses are shut off and drained for the winter. Water valves are located along same wall as the swamp coolers. The swamp cooler fans must be set to come on to prevent the greenhouses from overheating in sunny weather. The control box for each cooler is located on the wall by the appropriate cooler, these should be set to high vent and the main thermostat adjusted for winter conditions

3. Close side and roof vents in greenhouses 2, 3 and 4.

**Labeling**

Plants for permanent collections must be properly labeled to avoid confusion and loss of valuable plant accessions.

1. Plastic labels in individual pots should be written in pencil, include plant name, accession number, date, and initials of propagator.

2. Metal impression labels must include the accession number and plantname.3. Plants for the permanent screenhouse collections should not be moved out to the screenhouse until they have a permanent computer generated label.

4. Plants for the field collection should have a metal or plastic-paper label attached to the plant and/or the pot before they transfer to the tubehouse. Tubehouse plants are exposed to the elements and can easily lose their labels. Placing labels on the pots or low on the plant ensures that the label will not be easily lost if branches or tops break from wind damage.

**Clonal propagation for permanent collections**

(Also see annual schedule of greenhouse/screenhouse events)

*Rubus* Hardwood cuttings and tip layering is done in late summer or early fall. Cuttings taken earlier in the summer may not root well. Raspberry plants may be divided or root cuttings may be propagated in standard potting mix during the dormant season.

**Screenhouses**

The screenhouses are used to store healthy, pest-free and virus-free plants as permanent collections. The screenhouses are integral to the mission of the repository because they provide plant propagules to distribute to researchers and plant breeders world-wide.

Screenhouse Assignments:

Screenhouse 5. *Rubus*

Screenhouse 6. *Rubus*, *Mentha*, *Pycnanthemum, Ribes*

Screenhouse 7. Virus infected plants from all genera, non-cold hardy *Pyrus*, virus collections, overwintering plants for field. Chilean *Fragaria*.

Screenhouse 8. *Fragaria* (non-core), *Humulus*

Screenhouse 9. *Fragaria* (core)

Screenhouse 10. *Vaccinium* including cranberries

**Plant movement**

* All plants moving into any screenhouse from the field, shadetube, greenhouse, or from outside the repository must first enter the pest treatment room (GH 4-5) for inspection and pest elimination. Plants in a dormant condition may be placed in the screenhouse without entering the treatment room first, unless it is suspected that they have soil pests.
* Plants should not be removed from the pest treatment room until they have been examined \ treated for pests.
* Bench space should be requested from the greenhouse manager who will assign space and provide a bench label.
* Plants are not to be moved from bench to bench or house to house without notifying the greenhouse manager or person responsible for those plants. Inventory locations should be changed when plants are relocated.
* Keep doors closed whenever possible to minimize insect spread.

**Pest control**

Temperature extremes are greater in the screenhouses than in the greenhouses. Large temperature and humidity fluctuation aggravates pest problems and limits biological control options. In the absence of natural enemies, pest populations increase rapidly once they gain entry into the screenhouses. This is why "pest prevention" is so important to the screenhouse management. The pest management plan for the screenhouses should emphasize prevention of the introduction of pests and sanitation of dead or dying plant material.

* Insure the integrity of screens and other physical barriers. Holes in the screens are routinely inspected and repaired. All screenhouses are inspected thoroughly in early spring after the plastic is removed and all major repairs such as screen replacement completed at this time.
* Insure that double door entries are functional and used properly by all personnel and visitors.
* Limit access to sensitive areas. Screenhouses containing genera most susceptible to viruses, such as *Fragaria* and *Rubus* are off limits to the public and anyone coming directly from the field. Access to these two houses is limited to only essential personnel.
* Check clothing for insects prior to entering screenhouses. All persons should check their clothing for pests before entering the screenhouses.
* Maintain a weed free zone around the screenhouses. A strict weed control program is maintained in and around screenhouses. All weeds in the pots and under the benches are removed at least before they go to seed. Weeds in the pots are removed by hand; weeds under the benches and around the outside of the houses can be controlled with herbicides or with a propane torch. Weeds can harbor virus vectors, particularly aphids. The key to preventing vector establishment is to maintain clean weed-free screenhouses.
* Monitor insects. Sticky cards are used to monitor flying insect pests in all the screenhouses, particularly whiteflies, thrips, and fungus gnats.
* Eliminate debris. Fallen leaves and plant debris is vacuumed and removed from each house during the fall/winter.
* Flagging Codes:

Blue - Requests; generally means do not prune runners or stems.

Pink - Needed in tissue culture, same as above.

Red - Flowers or fruit needed.

Other colors change as needed.

* Fertilizer and biological control applications are to be noted and initialed on the clipboards provided. Other pesticide applications do not need to be noted there as we have a separate record of them.
* Emitters are to be checked in the spring and after mowing mint, pruning strawberries and blackberries or any other activity that may disturb the system. Emitter checking must be noted and initialed on the clipboard provided The emitters should be delivering as much water as possible.
* Irrigation filters are removed, cleaned and inspected in the early spring. Main lines along the walls are flushed at this time also.
* New batteries are installed in the irrigation control boxes that require them. This should be done in the spring before the weather gets hot.
* In each house is a form for keeping track of the maintenance activities.

**Freezing weather precautions**

* Roll down the plastic cold weather drapes on the screenhouses and close the doors and vents on the tubehouse.
* Check the pots for moisture and water if dry, plants in dry soil are easily damaged from freezing temperatures.
* Check that the water to the drip lines is turned off and that the overhead line is drained. If it is expected to get below freezing inside the screenhouses, turn the main water valve off. These valves are located the front of each screenhouse in a corner at ground level.
* Check that the water to the tubehouses is off; the main valve for this line is in a box in the ground in front of the pumphouse. The main valve should be shut and the drain valve opened. The overhead lines in the tube houses are equipped with valves on the ends which should also be opened to allow the water to drain out of the line so it will not freeze and break.
* Check the heating water supply valves in each screenhouse; make sure the main valves are open and any drain valves are shut.
* See that the thermostat controls are aligned with the black line. There is one control located in the center of each house.
* Plants to move into a greenhouse if the temperature will be below -10 o C (14 o F):
* Plants designated 'non-cold hardy' should be housed in the screenhouses and tubehouses.
* New plants for the field which are not also maintained in the screenhouse collections.

**Labeling**

* All plants in the permanent screenhouse collections must have a computer generated label attached to the pot. These labels are printed out on the laser printer by using a FoxPro label report. If a temporary plastic label is in the pot also, it need not be removed.
* Great care must be taken when labeling or replacing labels so that mix-ups do not occur. If a label is accidentally cut off it must be immediately replaced or a temporary label must be put on the plant.
* Plants belonging to collaborative researchers need to be labeled as to what the plants are, how long they are to remain, and who is responsible for them.
* Barcoding (Code 39) of the local number is used for inventory purposes. QR codes are attached for connecting to PI reference information on GRIN.

**Cultural practices**

Early in March all of the plants are fertilized with a slow release fertilizer, North Willamette Container Mix (10-4-3), and then again in June. Micronutrients (Peters STEM) are also applied early in March. Micronutrients are only applied to the permanent collections once a year, including the plants kept in greenhouse #4. A soluble fertilizer (15-16-17 and 15-0-15) formulated for soilless media may be applied early in the spring for quick greenup using the siphonex and applied by hand. Supplemental fertilization with soluble fertilizers may continue throughout the growing season, usually about once per month in the screenhouses. The 15-16-17 must be alternated with 15-0-15 to prevent the media from becoming too acidic. The non-woody plants should be repotted every 3 years to allow one collection per year to be repotted. Nearly all of the genera here are planted in standard potting mix (50% bark, 25% peat, 25% pumice) available from Rexius Forest By-products in Eugene.

***Rubus***

Culture: The plants are allowed to grow without trellising until the fruit is ripe, and then they are cut back, removing most of the current growth and all fruit. New growth is trellised as it grows to prevent the plants from tip layering into other pots and for easier access through the rows.

Soil mix and Fertilizer: Early in spring and again in 3 to 4 months the collection is given 1 tablespoon of slow release fertilizer that is scattered over the pot surface so that the emitters will water it in. If leaves are present on the plants the fertilizer should be watered off the foliage to prevent leaf burning. They are also given micronutrients early in the spring and supplemental soluble fertilizer applications.

Plants are repotted every 3 years. Plants are potted into 2 gallon pots in standard potting mix.

Pests and disease: The major pest of the screenhouse *Rubus* collection is spider mites. Beneficials are applied where possible but for specific outbreaks miticides are applied to keep the plants healthy. During the growing season, plants moved out to the screenhouses from the greenhouses have all the foliage pruned off to eliminate whitefly coming into the screenhouse. Applications of biocontrol agents are applied to keep the fungus gnat and coast fly populations under control.

Powdery mildew is rarely a problem in the *Rubus*, with the exception of one or two species. The plants are cut back to about 12 inches in the fall for overwintering. At least 12 inches of stem should be left, more if the plant is weak, so that the new growth will bloom for identification or other purposes the following year. The dead leaves and debris are vacuumed out of the pots and off the

**Walk-in coolers**

There are two coolers available for cold storage of plant materials and supplies. They are maintained at 4o C and equipped with a temperature alarm which is connected to the security system.

Walk-in Cooler 1: Plant materials and supplies.

Bench space is assigned and labeled for users. This cooler is cleaned annually. It is used for collaborative scientist research, plant request holding, new accession holding and backup, seed stratification, plant chilling and storage, grafting supplies, rubber bands and IPM supplies.

Walk-in Cooler 2: In-vitro culture collection.

**Data management and labeling.**

Data management is very important and great care must be taken when handling all aspects of accession identity and data pertaining to the accessions. The field personnel are responsible for entering accurate field inventory data into the system. Each plant on field map needs to be checked twice a year for accuracy of the data.

Labeling must be done carefully. All labels should have the genus code, local number, plant name, and if it is a permanent label, row and position number. If plastic tags are used they should be written with a #1 pencil. Aluminum tags are good temporary labels but must not be attached in a manner that might girdle the plant later. Permanent labels must be attached after one growing season or by the following spring if they are fall planted.

**Integrated pest management**

Integrated Pest Management (IPM) is a process consisting of the balanced use of cultural, biological, and chemical procedures that are environmentally compatible, economically feasible, and socially acceptable to reduce pest populations to tolerable levels. IPM recognizes that combining different strategies for pest management is more effective in the long run than a single strategy. This approach to pest management is consistent with the USDA's policy of promoting "sustainable systems" in agriculture.

The task of developing and implementing an IPM program for the repository is dynamic and presents several challenges. Substantially different pest management strategies are required for the greenhouses, screenhouses, and field plantings. The wide diversity of germplasm and corresponding pests means that techniques must be modified or invented in order fit this unique and highly complex situation.

The IPM program for the repository seeks to combine the use of cultural practices, biological control agents, quarantine procedures, physical exclusions and pesticides to effectively manage plant diseases, arthropod pests, vertebrate pests, and weeds in the greenhouses, screenhouses, and fields. It is recognized that for some situations, pesticides may offer the most effective method of managing pests, depending on the particular location and objective.

The objectives of the IPM program for the NCGR include:

1. Provide safe, acceptable plant protection.

2. Reduce dependence on pesticides.

3. Prevent the spread of diseases and viruses.

4. Use environmentally sound and sustainable practices.

5. Investigate/develop new pest management methods.

The goal of the Repository IPM program is to maintain pest populations at the lowest acceptable level with a minimum of pesticide use to provide a healthy plant environment and a safe environment for everyone working or visiting our facilities. We use the least toxic material to control pests whenever possible. Light horticultural oils, insecticidal soap and biological controls are used most often when cultural methods alone do not adequately control the problem.

The warm and humid environment of a greenhouse provides an ideal habitat for diseases, weeds, and many pests. In the absence of natural control factors, pest management in greenhouses is a constant challenge. Pest problems are compounded by the number of different projects, genera, and traffic in and out.

Key pests are those pests which can occur in large numbers or be very destructive to plant health. Secondary pests include other less important pests which usually occur in low numbers. There are eight key pests which occur in our greenhouses and screenhouses each year. A brief explanation of these pests, their damage, monitoring method, and the management strategies follows:

Aphids (order: Homoptera, Family: Aphididae) are a potential pest of all the genera cultured in the greenhouses.

Damage: Aphids have piercing-sucking mouthparts and feed by sucking the sap from the stems or leaves of plants. The most important aphid to control in our greenhouses is the green peach aphid *Myzus persicae*. These aphids are vectors of several important viruses and for this reason immediate action is required whenever aphids are observed in the greenhouses or screenhouses.

Monitoring: All plants are visually inspected throughout the growing season by the greenhouse personnel. All personnel are instructed to report any aphid observations to the greenhouse manager or assistant immediately.

Control: When aphids are found on one or a few plants, the infested plants are treated with an appropriate pesticide. If the infestation is widespread, the entire greenhouse is treated with a pesticide following all safety precautions. An essential element in aphid management is a strict cultural control program which includes sanitation, quarantine and inspection of incoming plant material, and the elimination of all weeds inside and outside in the immediate area of the greenhouses and screenhouses. Weeds such as little western bittercress, *Cardamine oligosperma*, serve as an alternate host for aphids. Dormant oil sprays are applied to all deciduous woody material in the screenhouses and tubehouses during the winter after all leaves and other debris have been removed. Evergreen *Vaccinium* should be treated with Sunspray rather than dormant oil to prevent leaf blackening.

Spider Mites The two-spotted spider mite *Tetranychus urticae* is the most common spider mite found in our greenhouses.

Damage: Spider mites feed by inserting their stylets into the plant surface and suck up the cell contents, causing white speckles on the leaves.

Monitoring Greenhouses are monitored weekly to detect the presence of spider mites. Since populations can increase rapidly in warm, dry environments early detection and control are necessary to maintain optimum plant health.

Control: Infestations are treated with beneficials or an appropriate miticide. During high temperatures, plants may also be misted daily with water since spider mites do not thrive in high humidity.

Greenhouse whitefly Adult greenhouse whiteflies *Trialeurodes vaporariorum* are about 1.5 mm long and are powdery white resembling tiny white moths.

Damage: Whiteflies are sap-sucking insects in both the adult and juvenile stages. Heavily infested plants may wilt, turn yellow and grow poorly.

Monitoring: Yellow sticky card traps are used to trap and monitor adults.

Control: Infestations are prevented by the introduction of the whitefly parasite *Encarsia formosa* prior to a large population buildup of whiteflies. It is recommended that these wasps be introduced when 1 whitefly per 50 plants is counted. If whitefly populations are high, nicotine smoke generators or another greenhouse fumigant may be applied to reduce populations prior to the introduction of the wasp. The female wasp lays an egg inside the immature whitefly scales. The parasite develops inside the scale, turning it black. When fully developed the new adult chews a small, round exit hole and emerges to begin searching for more whitefly scales to parasitize. Heavy infestations are controlled by repeated insecticidal sprays directed at the undersides of the leaves at the top of the plant. Avid applications for spider mites have been an effective control. Enstar, a commercially available whitefly growth regulator, can also be used without harming the wasp.

Root weevils Adult weevils are dark brown or black but some individuals appear light brown to chocolate in color. These beetles have long snouts and are unable to fly. Larvae are white legless grubs with brown heads. Root weevils spend the period from September to May in the larval stage in the soil around host plants, pupating and emerging as adults from May through August. In the protected environment of the greenhouses, development is continuous, but there is only one generation of weevils each year. Overwintering adults lay eggs into the late fall and begin laying eggs again in the spring with the onset of longer days and higher temperatures.

Damage: In general, adult weevils are inactive in daylight hours, resting in soil litter or protected areas. At night, temperature permitting, they feed on plant foliage. Adults feed on foliage producing a characteristic scalloping or notching effect along leaf margins. Larvae feed underground on the roots and crowns, often killing the plants. It is the larval stage which causes the most serious damage.

Monitoring: The greenhouses are monitored for evidence of adult weevils (leaf notching). It is too time consuming and disruptive to the plants to monitor for the larval stage.

Control: The larvae are controlled with predatory nematodes which are available commercially under the label Exhibit, CIBA-GEIGY. The nematodes are applied to all greenhouse, screenhouse, and shadehouse material as well as the cranberries. We apply the nematodes in the fall before the soil temperature in the pots falls below 50o F. If the soil temperature is too low then Orthene (acephate) drenches are applied. This method of larval control has been very effective. Adults are controlled by exclusion and sanitation in the greenhouses and screenhouses.

Powdery mildew is the most common disease problem in the greenhouses and screenhouses. This is a seasonal problem in the screenhouses occurring when the nights are warm and humidity is high. It is especially troublesome after the screenhouses are covered with plastic.

Damage: Small gray or white felt like patches of fungus develop on the foliage and stems. The terminals may become covered with masses of white mycelium and powdery spores.

Monitoring: Powdery mildew is monitored regularly along with other key pests.

Control: Culture is the primary control for powdery mildew. Plants in the greenhouses are spread apart and may be moved to where there is better air circulation. Air circulation can be increased by running the heating fans in the screenhouses with the hot water supply shut off. Fungicides are used when needed, usually in the spring and fall when the humidity is high.

Thrips Western flower thrips *Frankliniella occidentalis* are tiny insects that feed on leaves and flowers. Adult thrips are slender, less than 1/16 inch long, pale to dark yellow in color with feathery wings.

Damage: Both adults and larvae feed by scraping and rasping on plant tissue and sucking the escaping juices. The tissue around the feeding punctures becomes desiccated, giving the leaves or petals a flecked appearance.

Monitoring: Thrips are monitored year round in greenhouses with heating, and seasonally in the other greenhouses and screenhouses. Yellow sticky card traps are used to trap and monitor thrips. Traps are checked weekly and may be supplemented with potato slices placed on the soil for a few hours which attracts thrips as well as other pests.

Control: Hot-spots are treated with an appropriate insecticide three times, three to five days apart to break the life cycle. Thrips have shown a tendency to become resistant to pesticides so after treating three times with one, a different pesticide should be used the next time a hot spot develops in the same area or genus. Thrips thrive in plant debris so sanitation is very important.

Fungus gnats is a general term used to describe tiny flies in the families Sciaridae, Phoridae, and Mycetophilidae.

Damage: The larvae feed on root hairs and roots in the upper strata of the pots and later burrow into the stems resulting in extensive damage to seedlings and small plants. Fungus gnats are known to spread various root rots.

Monitoring: Adult fungus gnats are monitored with yellow sticky cards. Larval soil populations are monitored with potato slices placed on the pot surface which attracts the larvae. Control: Overwatering and poor sanitation are the primary causes of serious fungus gnat infestations. Therefore efforts are made to insure that plants are properly watered and that good sanitation is maintained. Because our standard potting mix is 75% organic material, fungi, algae and moss are very difficult to eradicate from the pots, therefore fungus gnats find it an ideal habitat and can easily get out of control. Moss and algae growth is discouraged on greenhouse benches, floors and walls. The greenhouses are treated with Gnatrol, a B.t. specific for fungus gnats, or Exhibit. The screenhouse plants are treated with Gnatrol or Exhibit as needed based on sticky card indications of adult populations.

Minor pests: There are a number of minor or secondary pests which occur in the greenhouses and screenhouses occasionally. These pests rarely cause serious damage and are usually controlled by the strategies implemented for the key pests. The minor pests which have been observed in the greenhouses include: slugs, snails, ants, earwigs, leafminers, leafrollers, mealybugs, leaf midges, springtails, sowbugs, millipedes and mice.

Slugs and snails can cause serious damage to herbaceous species particularly during the dormant season when they feed on roots and rhizomes. Potato slices are used to monitor for slugs and will also attract very small snails which may not leave obvious signs even during the growing season. Cultural controls for slugs and snails include removing plant debris from the surface of the pots including strawberry fruit.

**Greenhouse/ screenhouse annual schedule**

**JANUARY - FEBRUARY**

Apply dormant oil to all woody screenhouse material.

Finish vacuuming and cleanup in all screenhouses and tubehouses.

Rearrange plants.

Prune woody screenhouse plants.

Inventory all screenhouse collections.

Order supplies for the coming growing season.

**MARCH - APRIL**

Move recently propagated, established plants out to screenhouses while in a dormant, pest-free condition.

Apply pre-emergent herbicides in and around screenhouses, tubehouses and greenhouses.

Fumigate screenhouses just prior to plastic removal.

Fumigate greenhouses.

Remove plastic from screenhouses and shadetube #3.

Shut off heat in screenhouses.

Check all screenhouses for holes and repair.

Graft trees.

Move non-hardy plants in GH #2 back out to screenhouses.

Repot herbaceous plants - 3 year rotation.

Apply slow-release fertilizer to all screenhouse plants (March).

Apply slow release fertilizer to permanent greenhouse plants.

Apply slow release fertilizer to tubehouse plants.

Apply micronutrients to permanent greenhouse and screenhouse plants.

Begin regular liquid fertilizer applications to all houses.

Apply whitewash to greenhouses.

Begin regular flower and runner removal in strawberries.

Hook up and check all screenhouse irrigation systems.

Check all screenhouse emitters.

Replace batteries in irrigation control boxes.

Layer trees in greenhouse #2.

Begin weekly pest monitoring in screenhouses.

**MAY - JUNE**

Finish repotting.

Mark screenhouse plants for T.C. and request collection.

Cut Rubus back before fruit matures (mid-June).

Collect softwood cuttings and propagate.

Apply slow release fertilizer (June).

Begin regular emitter checks in screenhouses.

**JULY - AUGUST**

Collect softwood cuttings and propagate.

Weekly checking of mist bed and potting up new plants.

Weekly checking and repotting of new plants in greenhouse #1.

Trellising *Rubus*.

**SEPTEMBER - OCTOBER**

Tip layer Rubus and take cuttings for screenhouse collection.

Cut back fertilizer to greenhouse plants.

Move plants out for fall field planting.

Cut back water to screenhouses.

Apply nematodes to all screenhouses and tubehouses (Sept.)

Cover screenhouses with plastic.

Shut off screenhouse water and drain lines.

Turn on screenhouse heat supply.

Vacuum plant debris out of mint pots and check for slugs.

Cut down *Rubus*.

Weed *Rubus* pots.

Begin vacuuming and cleanup of all greenhouses.

Begin vacuuming and cleanup of all screenhouses.

Apply pre-emergent herbicides around tubehouses, screenhouses and greenhouses.

Check screenhouse floors for weeds and control as needed.

**NOVEMBER - DECEMBER**

Begin applying dormant oils to woody plants in screenhouses and tubehouses.

Update greenhouse inventory.

Check greenhouse floors for weeds and control as needed.

Begin handwatering of screenhouse and tubehouse plants.

Work on projects such as bench, trellis making or irrigation line.

Apply dormant oils to woody plants in screenhouses

**Seed management**

Management of the seed collection entails seven major functions, each composed of a varying number of subroutines. This chapter describes these functions, hopefully in sufficient detail to allow someone unfamiliar with the seed collection to effectively manage it. The eight major functions are:

1. Receipt of new fruit and seed

2. Germination

3. Seedling management

4. Maintenance of the seed inventory

5. Responding to seed requests

6. Monitoring

7. Seed Increases

8. Backup of seed at NCGRP

As a repository for a collection of global small fruit germplasm, new material is always arriving. To be represented in the field or screenhouse collections and to verify identity, new seeds must be germinated. Because the repository houses both cultivars and species material, and because of a history of clonal propagation, generated seedlings must be carefully labeled and guided to their ultimate destination in field, screenhouse, or species collections. A major function of the repository is the provision of small fruit germplasm to researchers and breeders around the world, and management of the seed collection includes responding to requests for seed. Of course, the seed collection manager should monitor storage conditions and seed viability, and when seed quantities drop, seed should be regenerated.

Occasionally a clean seed lot will be received, but more often than not seed must be extracted from fruit or otherwise cleaned before it is suitable for storage. When clean seed is received, it can immediately be dried; otherwise the material must be processed first.

Freshly collected fruit is usually received packaged in plastic bags. If it is not possible to begin processing this material promptly, it may be stored for up to a month in a refrigerator. Allowing the fruit to soften, begin decomposing, often results in easier extraction. However, excessive decomposition will result in the formation of fungal sclerotia and seed cleaning will be complicated.

Seed is usually extracted from small fruit using the method of Morrow et al. (1954). Seed is treated with pectinase overnight. The pectinase is rinsed out and the seeds are placed in a blender (the blades of which have been dulled), water is added, and the fruit macerated. Blender blades may be dulled using plastic tubing or duct tape; tape tends to remain on the blades longer than does plastic tubing. The goal is to beat the fruit to a viscous liquid without cutting or nicking seeds. The lowest setting of the blender for a duration of 20 to 60 seconds, varying with fruit condition, is generally sufficient.

The blended liquid is next poured into a large (1L) glass beaker. Water is added to fill the beaker and dilute the pulp solution. Sound, filled seeds settle to the bottom, while unfilled seeds and pulp remain in suspension. Stirring the solution once or twice during settling may allow seeds to settle which would otherwise remain suspended by floating pulp or attached air bubbles. After allowing the solution to remain undisturbed for about 60 seconds, the suspension is poured off leaving the settled seeds. The pitcher of the blender is then repeatedly rinsed, with the rinse water poured into the beaker, until all seeds have been washed from the pitcher. The liquid is again poured off, leaving filled seeds. Repeatedly adding water, stirring, and pouring off the suspension will give cleaner seeds. How long settling is allowed during this cleaning is best determined by observing the behavior of seeds and debris in the beaker. However, some debris must inevitably be removed using forceps.

After extraction, seeds are put into manila seed envelops and then into plastic-aluminum envelops for storage in -20oC chest freezers.

The blender should be disassembled and thoroughly rinsed between seed lots to avoid mixing seeds from one lot with another.

After cleaning, seeds are poured/scooped from the beaker onto a labeled brown (industrial weight) paper towel (or waxed paper) and allowed to air dry for at least three days. The paper towel is labeled with the number assigned by the collector and the species name in order to identify the accession. The information on the towel must also appear on the login sheet, so that once a local inventory number is assigned by the information manager it can be linked to the correct seed lot. With reference to the sample login sheet above, the paper towels could be labeled with the genus and species of the material and the number assigned by the collector. After air drying, seeds are rubbed/scrapped from the paper towel.

When very small quantities of fruit are received, simply plucking seeds from the fruit (e.g. strawberries) or crushing and smearing the fruit on a paper towel and subsequently picking seeds from the streak may prove easier.

When dried fruit is received, the seed will be particularly difficult to extract and clean. In most cases, separation of seeds and fruit is extremely difficult and tedious. Best results are usually obtained using some method of abrasion, such as a rub-board. Rubbing the material between your hands may also be effective.

***Rubus* seed management**

Dense, impermeable seed coats inhibit seed germination in this diverse genus. Of the genera stored at NCGR, *Rubus* is the most difficult to germinate. Chemical scarification or warm stratification followed by cold stratification is recommended, and the entire process may require in excess of six months. For each species, seed size, pigmentation, texture and, especially seed coat thickness are more important than crop type when determining optimal scarification treatments (Wada and Reed, 2011). Table 1 gives suggested scarification times for some *Rubus* species (Wada and Reed, 2011). Others should be measured for thickness of the seedcoat and hardness and given an appropriate scarification.

***Seed coat thickness and hardness:*** Seed coat thickness was measured for ten seed of each species. A Nikon SMZ 1000 stereomicroscopic Zoom Microscope (Nikon Instruments, Tokyo, Japan) was employed and measured with Infinity image capture and analysis software (Luminera Corporation, Ottawa, Canada). Measurements were taken in the center of the cut seed equidistant from the micropylar region and the hilar end. Hardness ratings of 1-5 were assigned after seed samples were soaked in deionized (DI) water for 2 days and hand sectioned with a scalpel. Subjective hardness grading was 1 soft, 2 slightly hard, 3 hard, 4 very hard, and 5 extremely hard.

***Seed scarification:*** Seeds (~300 per test tube) are soaked in 5-10 ml concentrated H2SO4 (98% +) in an ice bath for 20-30 minutes for thin seeded (<0.1 mm) or 1-3+ hours for thick seeded species (>0.1 mm). For example, *R. idaeus* 20 – 30 minutes, *R. occidentalis* 30-60 minutes, *R. ursinus* 1-2 hours and *R. argutus* derivatives/erect blackberries 3-5 hours. The reaction is ended with ice water being poured into the tubes and stirring them. They are poured through a strainer and then rinsed in a saturated sodium bicarbonate solution. While in the strainer they are run under running water and rubbed to remove much of the charring. Dipped again in sodium bicarbonate before being soaked for 5 days in calcium hypochlorite (Ca(ClO)2; 3g/L) completely dissolved in water with an excess of calcium hydroxide (Ca(OH)2; 3g/L). If needed, seeds are rubbed against a strainer again before stratification to remove any remaining carbonized portions of testa.

**Distributions and outreach**

*Rubus* germplasm is distributed as crown divisions, tip layers, cuttings, tissue cultures, pollen, flowers, or seed. Usually, for plant requests, cuttings are available for distribution in mid-winter. Crown divisions can also be available November through January during the dormant season. Cold stored tissue cultured plants in plastic packets or seeds can be distributed any time of year.

Since 1981, when the NCGR was dedicated, to 31 July 2015, more than 12,147 accessions have been distributed. The most distributed species was *Rubus idaeus* at accessions during that time.

Distribution of *Rubus* samples by year for NCGR-Corvallis

**Associated information**

**Genebank and/or crop-specific web site(s)**

NCGR website: <http://www.ars.usda.gov/main/site_main.htm?modecode=20-72-15-00>

*Rubus* catalog link: <http://www.ars.usda.gov/main//Docs.htm?docid=11370>

As of 1 October 2016, information will be searchable on the new GRIN-Global database.

<http://www.grin-global.org/index.php/Main_Page>

**Plant genetic resource research associated with the NPGS**

* Project sponsored by USDA NIFA Specialty Crop Research Initiative RosBREED to link economically useful genes, such as those for red stele (*Phytophthora fragariae*) and continuous or repeat blooming, with specific genotypes in the collection.

**Future goals and emphases**

* Obtain wild *Rubus* with resistance to root rots
* Obtain wild *Rubus* with resistance to foliar and fruit diseases
* Obtain primary, secondary, tertiary crop wild relatives with high fruit qualities
* Obtain wild *Rubus* that are repeat or primocane blooming.
* Obtain wild Rubus with low chilling, drought, and heat tolerance.
* Obtain heritage cultivars from the US
* Obtain heritage cultivars from Europe

**Significant accomplishments**

* Significant plant collections from the US in multiple collecting trips over 30 years.
* Significant plant collections for *Rubus* from Guizhou, China (1996), and Pakistan (1988).
* Conservation of heritage *Rubus* dating back to European cultivars for several hundred years.
* Conservation of significant genotypes from the Oregon and USDA programs in Maryland.
* Evaluated Asian *Rubus* species for characteristics and breeding possibilities.
* Evaluated wild *Rubus* germplasm for aphid and virus resistance.
* Evaluated wild *Rubus* germplasm for Verticillium wilt resistance.
* Optimized growing media for red raspberry cultivars in tissue culture
* DNA markers have been developed for fingerprinting *Rubus* cultivars.
* DNA markers for perpetual blooming and other traits are under investigation.
* Ploidy levels by chromosome counts and flow cytometry have been determined for most of the collection.
* Have worked with grower groups to label raspberries and blackberries with barcodes and QR codes.

**Curatorial, managerial and research capacities and tools**

**Staffing**

0.1 FTE Cat. 4 support scientist Curator

0.1 FTE Cat. 4 virus cleanup Scientist Plant Pathologist (tissue culture)

0.1 FTE Cat. 4 Research Geneticist for identity confirmation/diversity assessment

0.1 FTE Program Assistant (GS-7)

0.1 FTE Bio Sci Res Tech (GS 9) – greenhouse manager

0.1 FTE Bio Sci Res Tech (GS 9) – tissue culture technician

0.1 FTE Bio Sci Res Tech (GS 9) – distribution

0.5 FTE Bio aid (GS 5) – propagation

0.1 FTE time slip labor- flower removal, plant management

1.3 FTE total labor for *Rubus* efforts

**Facilities and equipment ft2 m2**

2.5 Screenhouses for *Rubus* only 9,000 1,050

(below only 1/10 for *Rubus*)

Main office and laboratory space 9,830 929

Four greenhouses 10,229 937

Headhouse 6,500 614

One shadehouse 1,720 164

Boiler room 400 38

Shop work area 1,704 161

Two storage sheds 3,960 374

Two walk-in coolers 360 36

North Farm building 2,220 210

Additional facilities and support

Fuel Tanks

Above ground diesel 2 @ 500 gal

Above ground gasoline 1 @ 500 gal

4 wells

Land

Buildings and Grounds 5 acres (2.23 hectares)

(25 year lease through 2029)

Planted (other non-*Rubus* crops)

20 acres (8.09 hectares) at 33447 Peoria Road, Corvallis, OR 97333

(Agreement with OSU Department of Horticulture on Lewis Brown Farm)

Additional Plantings 42 acres (17 hectares) USDA-ARS owner

33707 S.E. Peoria Road, Corvallis, OR 97333

Staffing for Facilities Management

Location Engineering Technician GS-9 available for consultation and advice

Unit Maintenance Technician WG-5 provides 0.15 FTE of facilities maintenance.

Janitor WG-1, 0.15 FTE

**Equipment**

Tissue culture laboratory (media prep, culturing, growth room, cryogenic option)

Molecular marker laboratory (molecular marker determination)

Pathogen testing laboratory (bio assays, ELISA, PCR)

Plant propagation equipment (mistbed, propagation houses, quarantine facility)

Field propagation

**Fiscal and operational resources**

Federal funding to support federal *Rubus* germplasm management at NCGR- Corvallis: FY 2015 – $156,400.

About $10,000 per year to fund germplasm evaluation proposals from USDA Crop Germplasm Committee evaluation grants.

**Other goals for genetic resource capacities (germplasm collections, in situ reserves, specialized genetic/genomic stocks, associated information, research and managerial capacities and tools, and industry/technical specialists/organizations)**

* Establish in situ *Rubus* conservation within the US including lower 48 and Alaska and Hawaii. Work with National Parks, National Forests, Heritage Botanists, State Collections, Private land resources
* Verify each of the genotypes in the collection using molecular markers. (SSR or SNP).
* Establish tissue culture collection of complete cultivar collection.
* Store examples of *Rubus* species both at NCGRP- Ft. Collins and at Svalbard Global Seed Vault, Norway.

**Prospects and future developments**

* Produce pathogen negative germplasm for distribution of each clone.
* Confirm identity of clones using efficient DNA marker techniques.
* Examine phylogeny of world *Rubus* species.

**References**

Bastas, K.K. and Sahin, F. 2014. Screening of Blackberry and Raspberry Cultivars for Susceptibility to Fire Blight Disease in Turkey. HortScience 49: 1492-1497.

Buckley, B., Moore, J.N. and Clark, J.R. 1995. Blackberry cultivars differ in susceptibility to rosette disease. Fruit Var. J. *49,* 235-238.

Bushakra, J.M., D.W. Bryant, M. Dossett, K.J. Vining, R. VanBuren, B.S. Gilmore, J. Lee, T.C. Mockler, C.E. Finn, and N.V. Bassil. 2015. A genetic linkage map of black raspberry (*Rubus occidentalis*) and the mapping of *Ag4* conferring resistance to the aphid *Amphorophora agathonica.* Theor. Appl. Gen. doi:[10.1007/s00122-015-2541-x](http://dx.doi.org/10.1007%2Fs00122-015-2541-x)Carlen, C., C. A. Baroffio, and P. Richoz.2015. *Drosophila suzukii* in Switzerland: survey 2012-14 and control methods. The XI Rubus and Ribes Symposium Program. Ashville, North Carolina. p. 74-75. (Abst.)

Clark, J.R. and C.E. Finn, 2011. p. 27-43. Blackberry Breeding and Genetics. In: H. Flachowsky and V-M. Hanke (eds.) Methods in Temperate Fruit Breeding. Fruit, Vegetable and Cereal Science and Biotechnology 5 (Special Issue 1) Global Science Books, Ltd., UK.

Clark, J.R., E.T. Stafne, H.K. Hall, and C.E. Finn. 2007. Blackberry breeding and genetics. Plant Breeding Reviews 29:19-144.

Collins, M. 2000. Medieval herbals: The illustrative traditions. The British Library, London, p. 39-105.

Connolly, T.J. 1999. Newberry Crater: A ten-thousand-year record of human occupation and environmental change in the basin-plateau borderlands. Anthropological Papers #121. Univ. Utah, Salt Lake City.

Daubeny, H.A. 1996. Brambles. p. 109-190. In: J. Janick, and J.N. Moore (eds.), Fruit Breeding: Vol. II Vine and small fruit crops. Wiley, New York.

Darrow, G.M. 1937. Blackberry and raspberry improvement. p. 496-533. In: U.S.D.A. Yearbook of Agr., 1937. Government Printing Office, Washington DC.

Diekmann M. Frison, E.A., and Putter, T. (eds.) 1994. FAO/IPGRI Technical Guidelines for the Safe Movement of Small Fruit Germplasm. Food and Agriculture Organization of the United Nations. Rome/International Plant Genetic Resources Institute, Rome.

Dossett, M. and C. Kempler. 2015. Breeding raspberries for aphid resistance in British Columbia: Progress and challenges. Proceedings of the XI Rubus and Ribes Symposium Ashville, North Carolina. p 87. (Abst.)

FAOSTAT, 2015.  [http://faostat3.fao.org/browse/Q/QC/E 12 Aug 2015](%20http://faostat3.fao.org/browse/Q/QC/E%2012%20Aug%202015).

Finn, C. 2001. Trailing blackberries: from clear‑cuts to your table. HortScience 36:236-238.

Finn, C.E. and J.R. Clark. 2012. p. 151-190, Blackberry. In: M.L. Badenes and D.H. Byrne (eds.). Handbook of Plant Breeding: Volume 8: Fruit breeding. Springer, New York.

Finn, C.E. and V.H. Knight. 2002. What's going on in the world of *Rubus* breeding? Acta Hort. 585:31-38.

Finn, C.E., B.C. Strik, B.M. Yorgey, M. Qian, R.R. Martin, and M. Peterson. 2010. ‘Wild Treasure’ thornless trailing blackberry. HortScience 45:434-436.

Finn, C. H. Swartz, P.P. Moore, J.R. Ballington, C. Kempler. 2001. Breeders experiences with *Rubus* species. [http://www.ars‑grin.gov/cor/rubus/rubus.uses.html](http://www.arsgrin.gov/cor/rubus/rubus.uses.html) 8 Aug. 2015

Gergerich, R.C., Welliver, R., Gettys, S., Osterbauer, N.K., Kamenidou, S., Martin, R.R., Golino, D., Eastwell, K., Fuchs, M., Vidalakis, G. and Tzanetakis, I.E. 2015. Safeguarding fruit crops in the age of agricultural globalization. Plant Disease 99: 176-187

Grabke, A., Fernández-Ortuño, D., Amiri, A., Li, X., Peres, N. A., Smith, P. and Schnabel, G. 2014. Characterization of iprodione resistance in *Botrytis cinerea* from strawberry and blackberry. Phytopathology104:396-402.

Gupton, C.L. and Smith, B.J. 1997. Heritability of rosette resistance in blackberry. HortScience 32:940.

Hall, H.K., Hummer, K.E., Jamieson, A.R., Jennings, S.N., andWeber, C.A. 2009. Raspberry breeding and genetics. pp. 39-382 in: J. Janick (ed.) Plant breeding reviews Vol. 32. Wiley-Blackwell, Hoboken, NJ.

Halgren, A.B., Tzanetakis, I.E. and Martin,R.R. 2007. Identification, characterization, and detection of Black raspberry necrosis virus. Phytopathology97: 44-50.

Hedrick, U.P 1925. Small fruits of New York. J.B. Lyon Company, Albany.

Hsu, H.Y., Y.P. Chen, S.J. Shen, C.S. Hsu, C.C. Chen, and H.C. Chang. 1986. Oriental material medica: A concise guide. Oriental healing Arts Inst., Long Beach, Cal.

Hultén, E. 1968. Flora of Alaska and Neighboring Territories: A manual of the vascular plants. Stanford University Press, Stanford, CA.

Hummer, K. 2010. *Rubus* pharmacology: antiquity to the present HortScience 45: 1587-1591.

Hummer, K.E. and D.N. Peacock. 1994. Seed dimension and weight of selected *Rubus* species. *HortScience*. 29(9):1034-1036.

Hummer, K. and Janick, J. 2007. *Rubus* iconography: antiquity to the Renaissance. *Acta Hort*. 759:89-106.

Hummer, K. and H. Hall. 2013. p. 1-18, Raspberries:introduction and description. In R. Funt and H. Hall (eds.) Raspberries. CABI, Wallingford, UK.

Hummer, K.E., J.R. Ballington, C.E. Finn, and T.M. Davis. 2013. Asian germplasm influence in American berry crops. HortScience 48:1090-1094.

Hummer, K. N. Bassil, and L. Alice. 2015. *Rubus* species ploidy assessment. Acta Hort. In review.

IUCN. 2015. International Union for Conservation of Nature <http://www.iucn.org/> accessed 8/8/2015.

Janick, J. and K.E. Hummer. 2012. The 1500th Anniversary (512-2012) of the Juliana Anicia Codex: An illustrated Dioscoridean Recension. Chronica Hort. 52:9-15.

Jennings, D.L. 1988. Raspberries and blackberries: Their breeding, diseases and growth. Academic Press, London.

Kempler, C., H. Hall, and C.E. Finn. 2012. p. 263-304, Raspberry. In: M.L. Badenes and D. H. Byrne (eds.). Handbook of plant breeding: Volume 8: Fruit breeding. Springer, New York.

Kidd, J.P., Clark, J.R., Fenn, P. and Smith, B.J. 2004. Evaluation of post-harvest disease resistance in blackberry genotypes. In: Arkansas Agric. Exp. Station Hort. Studies 2003, Research Series 520, University of Arkansas, Fayetteville, Arkansas. p. 18-19.

Lee, J.C., Bruck, D.J., Curry, H., Edwards, D., Haviland, D.R., Steenwyk, R.A.V. and Yorgey, B.M. 2011. The susceptibility of small fruits and cherries to the spotted-wing Drosophila, *Drosophila suzukii*. Pest Manag. Sci. 67:1358-67.

Li, X.P., Kerrigan J., Chai W.X., Schnabel, G. 2012. Botrytis caroliniana, a new species isolated from blackberry in South Carolina. Mycologia 104:650–658, doi:10.3852/11-218.

Lipe, J.A. 1986. Keys to profitable blackberry production in Texas. Texas Agric. Ext. Serv. B-1560. Texas A&M University, College Station, Texas.

Markow, T.A., and O’Grady, P.M. 2006. Drosophila: a guide to species identification and use. Elsevier Academic Press. New York, N.Y. 259 pp.

Martin, R.R., MacFarlane, S., Sabanadzovic, S., Quito-Avila, D.F., Poudel, B., and Tzanetakis, I.E. 2013. Viruses and virus diseases of *Rubus*.  Plant Disease. 97:168-182.

Martin, R.R. (ed.) 2004. X International Symposium on Small Fruit Virus Diseases. Acta Hort: 656.

Morrow, E.B., G.M. Darrow, and D.H. Scott. 1954. A quick method of cleaning berry seed for breeders. Proceedings of the American Society for Horticultural Science. 63:265.

Moyer, R.A., K.E. Hummer, C.E. Finn, B. Frei and R.E. Wrolstad. 2002a. Anthocyanins, phenolics, and antioxidant capacity in diverse small fruits: *Vaccinium*, *Rubus*, and *Ribes*. J. Agric. Food Chem. 50:519-525.

Moyer, R. K. Hummer, R.E. Wrolstad, C. Finn. 2002b. Antioxidant compounds in diverse *Rubus* and *Ribes* germplasm. Acta Hort. 585: 501-505.

Nunney, L., D.L. Hopkins, L.D. Morano, S.E. Russell, and R. Stouthamer. 2014. Intersubspecific recombination in Xylella fastidiosa strains native to the United States: Infection of novel hosts associated with an unsuccessful invasion. Appl. Environ. Microbiol. 80:1159–1169

Organic Production Survey, 2015. <http://www.nass.usda.gov/Surveys/Organic_Production_Survey/> accessed 8/8/2015

Peacock, D.N. and K.E. Hummer. 1994. *Rubus* seed sensitivity to sodium hypochlorite. HortScience 29(5):506.

Powney, R., Smits, T.H.M., Sawbridge, T., Frey, B., Blom, J., Frey, J.E., Plummer, K.M., Beer, S.V., Luck, J., Duffy,B., and Rodoni, B. 2011. Genome sequence of an *Erwinia amylovora* strain with restricted pathogenicity to *Rubus* plants. J. Bacteriol. 193:785–786

Schwab W, Schaart J, Rosati C .2009. Functional molecular biology research in *Fragaria.* In: Folta KM, Gardiner SE (eds.) Genetics and Genomics of Rosaceae: Crops and Models, vol 6. Springer, New York, USA, pp 457-486.

Smith, B.J. and Fox, J.A. 1991. Rosette. In: Compendium of Raspberry and Blackberry Diseases and Insects, APS Press, St. Paul, Minnesota. p. 13-15.

Smith, B.J. and Miller-Butler, M. 201X. Evaluation of blackberry cultivars adapted to the southeastern United States for susceptibility to post-harvest fruit diseases. Acta Hort. in press.

Strik, B.C., J.R. Clark, C.E. Finn, and M.P. Banados. 2007. Worldwide production of blackberries, 1995 to 2005 and predictions for growth. HortTechnology 17:205–213.

Thompson, M. M. 1995a. Chromosome numbers of *Rubus* species at the National Clonal Germplasm Repository. HortScience 30:1447–1452.

Thompson, M. M. 1995b. Chromosome numbers of *Rubus* cultivars at the National Clonal Germplasm Repository. HortScience 30: 1453–1456.

Thompson, M. M. 1997. Survey of chromosome number in *Rubus* (Rosaceae: Rosoideae). Annals Missouri Bot. Garden 84:129-165.

USDA, 2015 USDA, ARS, National Genetic Resources Program. *Germplasm Resources Information Network - (GRIN)* [Online Database]. National Germplasm Resources Laboratory, Beltsville, Maryland. Accessed 13August 2015.  
URL: http://www.ars-grin.gov/cgi-bin/npgs/html/tax\_search.pl

USDA-National Agricultural Statistics Service, Noncitrus Fruits and Nuts 2013 Summary, 16 November 2013.

Wada, S., Kennedy, J.A., and Reed, B.M. 2011. Seed-coat anatomy and proanthocyanidins contribute to the dormancy of *Rubus* seed. Scientia Hort. 130:762-768.

Wada, S., and Reed, B.M. 2011a. Optimized scarification protocols improve germination of diverse *Rubus* germplasm. Scientia Hort. 130:660-664.

Wada, S., and Reed, B.M. 2011b. Standardizing germination protocols for diverse raspberry and blackberry species. Scientia Hort. 132:42-49.

Wang, Q., Cuellar, W.J., Rajamaki M-L., Hirata Y. and Valkonen J.P.T. 2009. Cryotherapy of shoot tips: novel pathogen eradication method. Trends in Plant Science 14: 119-122.

**7. Appendices**

Table 1. *Rubus* species in GRIN (as of August 2015)

1. Rubus adenotrichos ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20adenotrichos))
2. Rubus allegheniensis ( [39 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20allegheniensis))
3. Rubus alumnus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20alumnus))
4. Rubus amphidasys ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20amphidasys))
5. Rubus anglocandicans ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20anglocandicans))
6. Rubus arcticus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20arcticus))
7. Rubus arcticus nothosubsp. stellarcticus ( [6 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20arcticus%20nothosubsp.%20stellarcticus))
8. Rubus arcticus subsp. arcticus ( [7 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20arcticus%20subsp.%20arcticus))
9. Rubus arcticus subsp. stellatus ( [6 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20arcticus%20subsp.%20stellatus))
10. Rubus argutus ( [7 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20argutus))
11. Rubus armeniacus ( [25 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20armeniacus))
12. Rubus assamensis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20assamensis))
13. Rubus aurantiacus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20aurantiacus))
14. Rubus axillaris ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20axillaris))
15. Rubus bambusarum ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20bambusarum))
16. Rubus bartonianus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20bartonianus))
17. Rubus bavaricus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20bavaricus))
18. Rubus biflorus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20biflorus))
19. Rubus bogotensis ( [5 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20bogotensis))
20. Rubus briareus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20briareus))
21. Rubus buergeri ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20buergeri))
22. Rubus bullatus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20bullatus))
23. Rubus caesius ( [28 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20caesius))
24. Rubus camptostachys ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20camptostachys))
25. Rubus canadensis ( [15 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20canadensis))
26. Rubus canescens ( [9 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20canescens))
27. Rubus caucasicus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20caucasicus))
28. Rubus chamaemorus ( [29 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20chamaemorus))
29. Rubus chingii ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20chingii))
30. Rubus cissoides ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20cissoides))
31. Rubus clinocephalus ( [9 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20clinocephalus))
32. Rubus cockburnianus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20cockburnianus))
33. Rubus columellaris ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20columellaris))
34. Rubus conothyrsoides ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20conothyrsoides))
35. Rubus corchorifolius ( [7 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20corchorifolius))
36. Rubus coreanus ( [10 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20coreanus))
37. Rubus coriaceus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20coriaceus))
38. Rubus corylifolius aggr. ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20corylifolius%20aggr.))
39. Rubus crataegifolius ( [17 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20crataegifolius))
40. Rubus croceacanthus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20croceacanthus))
41. Rubus cuneifolius ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20cuneifolius))
42. Rubus cyri ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20cyri))
43. Rubus deliciosus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20deliciosus))
44. Rubus divaricatus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20divaricatus))
45. Rubus echinatus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20echinatus))
46. Rubus ellipticus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ellipticus))
47. Rubus enslenii ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20enslenii))
48. Rubus erythrops ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20erythrops))
49. Rubus eustephanos ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20eustephanos))
50. Rubus fabrimontanus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20fabrimontanus))
51. Rubus flagellaris ( [12 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20flagellaris))
52. Rubus floribundus ( [9 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20floribundus))
53. Rubus flosculosus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20flosculosus))
54. Rubus fockeanus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20fockeanus))
55. Rubus formosensis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20formosensis))
56. Rubus fruticosus aggr. ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20fruticosus%20aggr.))
57. Rubus geoides ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20geoides))
58. Rubus georgicus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20georgicus))
59. Rubus glaucus ( [30 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20glaucus))
60. Rubus grabowskii ( [19 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20grabowskii))
61. Rubus hartmanii ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20hartmanii))
62. Rubus hawaiensis ( [14 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20hawaiensis))
63. Rubus hirsutus ( [12 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20hirsutus))
64. Rubus hirtus ( [13 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20hirtus))
65. Rubus hispidus ( [10 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20hispidus))
66. Rubus hoffmeisterianus ( [7 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20hoffmeisterianus))
67. Rubus humulifolius ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20humulifolius))
68. Rubus hunanensis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20hunanensis))
69. Rubus hybr. ( [164 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20hybr.))
70. Rubus hypargyrus var. niveus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20hypargyrus%20var.%20niveus))
71. Rubus ichangensis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ichangensis))
72. Rubus idaeus subsp. idaeus ( [365 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20idaeus%20subsp.%20idaeus))
73. Rubus idaeus subsp. strigosus ( [119 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20idaeus%20subsp.%20strigosus))
74. Rubus ikenoensis ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ikenoensis))
75. Rubus illecebrosus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20illecebrosus))
76. Rubus inermis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20inermis))
77. Rubus innominatus ( [6 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20innominatus))
78. Rubus insularis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20insularis))
79. Rubus irenaeus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20irenaeus))
80. Rubus irritans ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20irritans))
81. Rubus kennedyanus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20kennedyanus))
82. Rubus komarovii ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20komarovii))
83. Rubus laciniatus ( [10 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20laciniatus))
84. Rubus lambertianus ( [7 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20lambertianus))
85. Rubus lambertianus var. glaber ( [5 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20lambertianus%20var.%20glaber))
86. Rubus lamprocaulos ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20lamprocaulos))
87. Rubus lasiococcus ( [10 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20lasiococcus))
88. Rubus lasiostylus ( [7 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20lasiostylus))
89. Rubus lasiostylus var. hubeiensis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20lasiostylus%20var.%20hubeiensis))
90. Rubus leucodermis ( [50 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20leucodermis))
91. Rubus lindebergii ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20lindebergii))
92. Rubus lineatus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20lineatus))
93. Rubus loganobaccus ( [20 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20loganobaccus))
94. Rubus macilentus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20macilentus))
95. Rubus macvaughianus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20macvaughianus))
96. Rubus megalococcus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20megalococcus))
97. Rubus mesogaeus ( [5 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20mesogaeus))
98. Rubus microphyllus var. subcrataegifolius ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20microphyllus%20var.%20subcrataegifolius))
99. Rubus minusculus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20minusculus))
100. Rubus miszczenkoi ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20miszczenkoi))
101. Rubus moluccanus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20moluccanus))
102. Rubus moluccanus var. moluccanus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20moluccanus%20var.%20moluccanus))
103. Rubus moschus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20moschus))
104. Rubus mulleri ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20mulleri))
105. Rubus neglectus ( [15 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20neglectus))
106. Rubus neomexicanus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20neomexicanus))
107. Rubus nepalensis ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20nepalensis))
108. Rubus nessensis ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20nessensis))
109. Rubus nivalis ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20nivalis))
110. Rubus niveus ( [17 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20niveus))
111. Rubus nubigenus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20nubigenus))
112. Rubus occidentalis ( [227 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20occidentalis))
113. Rubus odoratus ( [11 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20odoratus))
114. Rubus ostroviensis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ostroviensis))
115. Rubus palmatus ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20palmatus))
116. Rubus palmatus var. coptophyllus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20palmatus%20var.%20coptophyllus))
117. Rubus parviflorus ( [32 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20parviflorus))
118. Rubus parvifolius ( [36 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20parvifolius))
119. Rubus parvus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20parvus))
120. Rubus pectinellus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pectinellus))
121. Rubus pedatus ( [14 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pedatus))
122. Rubus pedemontanus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pedemontanus))
123. Rubus pensilvanicus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pensilvanicus))
124. Rubus pentalobus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pentalobus))
125. Rubus phoenicolasius ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20phoenicolasius))
126. Rubus plicatus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20plicatus))
127. Rubus polyanthemus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20polyanthemus))
128. Rubus praecox ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20praecox))
129. Rubus pseudochamaemorus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pseudochamaemorus))
130. Rubus pseudojaponicus ( [9 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pseudojaponicus))
131. Rubus pubescens ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pubescens))
132. Rubus pungens ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pungens))
133. Rubus pyramidalis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20pyramidalis))
134. Rubus radula ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20radula))
135. Rubus rhombifolius ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20rhombifolius))
136. Rubus riograndis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20riograndis))
137. Rubus roseus ( [5 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20roseus))
138. Rubus rosifolius ( [8 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20rosifolius))
139. Rubus rugosus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20rugosus))
140. Rubus sachalinensis ( [49 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20sachalinensis))
141. Rubus sanctus ( [8 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20sanctus))
142. Rubus saxatilis ( [8 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20saxatilis))
143. Rubus schleicheri ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20schleicheri))
144. Rubus schmidelioides ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20schmidelioides))
145. Rubus seebergensis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20seebergensis))
146. Rubus separinus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20separinus))
147. Rubus setchuenensis ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20setchuenensis))
148. Rubus sieboldii ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20sieboldii))
149. Rubus simplex ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20simplex))
150. Rubus slesvicensis ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20slesvicensis))
151. Rubus spectabilis ( [54 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20spectabilis))
152. Rubus spp. ( [89 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20spp.))
153. Rubus sprengelii ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20sprengelii))
154. Rubus squarrosus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20squarrosus))
155. Rubus sumatranus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20sumatranus))
156. Rubus swinhoei ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20swinhoei))
157. Rubus taiwanicola ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20taiwanicola))
158. Rubus takesimensis ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20takesimensis))
159. Rubus tephrodes ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20tephrodes))
160. Rubus tephrodes var. ampliflorus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20tephrodes%20var.%20ampliflorus))
161. Rubus thibetanus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20thibetanus))
162. Rubus trianthus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20trianthus))
163. Rubus tricolor ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20tricolor))
164. Rubus trifidus ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20trifidus))
165. Rubus trivialis ( [25 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20trivialis))
166. Rubus tsangiorum ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20tsangiorum))
167. Rubus ulmifolius ( [20 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ulmifolius))
168. Rubus ursinus ( [83 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ursinus))
169. Rubus ursinus subsp. macropetalus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20ursinus%20subsp.%20macropetalus))
170. Rubus urticifolius ( [4 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20urticifolius))
171. Rubus vermontanus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20vermontanus))
172. Rubus vernus ( [3 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20vernus))
173. Rubus vestitus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20vestitus))
174. Rubus wahlbergii ( [2 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20wahlbergii))
175. Rubus wallichianus ( [1 Accessions](http://www.ars-grin.gov/cgi-bin/npgs/html/tax_site_acc.pl?COR%20Rubus%20wallichianus))

**Appendix Table 2. Viruses that infect *Rubus* (from Martin et al., 2013).**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Table 1.** *Rubus* viruses, names, acronyms, natural mode of transmission, genera, means of laboratory testing, and regional occurrence | | | | | | | | |
|  | **Virus name** | **Acronym** | **Mode of transmission** | **Genus** | **Regional occurrencea**  **Laboratory detectionb NA SA Europe Asia Aust/NZReferences** | | | | |
|  | Apple mosaic | ApMV | Pollen, seed | Ilarvirus | ELISA, RT-PCR + + | + | + | + | 6, 35 |
|  | Arabis mosaic | ArMV | Nematode, seed | Nepovirus | ELISA, RT-PCR + + | + | + | + | 68, 76, 77 |
|  | Beet pseudo yellows | BPYV | Whitefly | Crinivirus | RT-PCR + + | + | + | + | 127, 137 |
|  | Blackberry chlorotic ringspot | BCRV | Pollen, seed | Ilarvirus | RT-PCR + | + |  |  | 50, 87 |
|  | Blackberry virus E | BVE |  | Unassigned | RT-PCR + |  |  |  | 101 |
|  | Blackberry virus S | BlVS |  | Marafivirus | RT-PCR + |  |  |  | 99 |
|  | Blackberry virus Y | BVY |  | Brambyvirus | RT-PCR + |  |  |  | 119, 120 |
|  | Blackberry yellow vein associated | BYVaV | Whitefly | Crinivirus | RT-PCR + |  |  |  | 118, 130 |
|  | Black raspberry necrosis | BRNV | Aphid | Unassigned | RT-PCR + | + |  | + | 33, 39, 53, 110 |
|  | Cherry leaf roll | CLRV | Nematode, pollen, seed | Nepovirus | ELISA, RT-PCR + + | + | + | + | 3, 54 |
|  | Cherry rasp leaf | CRLV | Nematode | Cheravirus | RT-PCR + |  |  |  | 114 |
|  | Grapevine Syrah virus 1 | GSyV-1 |  | Marafivirus | RT-PCR + + |  |  |  | 2, 27, 100 |
|  | Impatiens necrotic spot | INSV | Thrips | Tospovirus | ELISA, RT-PCR + + | + | + | + | 83, 124 |
|  | Raspberry bushy dwarf | RBDV | Pollen, seed | Idaeovirus | ELISA, RT-PCR + + | + | + | + | 16, 114 |
|  | Raspberry latent | RpLV | Aphid | Unassigned | RT-PCR + |  |  |  | 90 |
|  | Raspberry leaf blotch | RLBV | Mites | Emaravirus | RT-PCR | + |  |  | 73 |
|  | Raspberry leaf curl | RpLCV | Aphid | No Info. | + |  |  |  | 114 |
|  | Raspberry leaf mottle | RLMV | Aphid | Closterovirus | RT-PCR + | + |  |  | 8, 71, 125 |
|  | Raspberry ringspot | RpRSV | Nematode, pollen, seed | Nepovirus | ELISA, RT-PCR | + | + |  | 80, 114 |
|  | Raspberry vein chlorosis | RVCV | Aphid | Rhabdovirus | RT-PCR | + |  | + | 55, 69, 114 |
|  | Rubus canadensis virus 1 | RuCV-1 |  | Foveavirus | RT-PCR + |  |  |  | 102 |
|  | Rubus yellow net | RYNV | Aphid | Badnavirus | RT-PCR + | + |  |  | 49, 114 |
|  | Sowbane mosaic virus | SoMV | Pollen, seed | Sobemovirus | ELISA, RT-PCR + + | + | + | + | 56, 69 |
|  | Strawberry latent ringspot | SLRSV | Nematode | Unassigned | ELISA, RT-PCR + + | + | + | + | 1, 30, 34, 129 |
|  | Strawberry necrotic shock | SNSV | Thrips, pollen, seed | Ilarvirus | ELISA, RT-PCR + | + | + | + | 62, 106, 126 |
|  | Tobacco ringspot | TRSV | Nematode, pollen, seed | Nepovirus | ELISA, RT-PCR + + | + | + | + | 114 |
|  | Tomato black ring | TBRV | Nematode, pollen, seed | Nepovirus | ELISA, RT-PCR | + | + |  | 65, 78, 114 |
|  | Tomato ringspot | ToRSV | Nematode, pollen, seed | Nepovirus | ELISA, RT-PCR + + | + | + | + | 4, 114 |
|  | Wineberry latent/ Blackberry calico | WLV/ BCV | Unassigned | | + | + |  |  | 114 |
| 1. Regional occurrence included all hosts of the viruses and not only Rubus; NA = North America, SA = South America, Aust = Australia, NZ = New Zealand. 2. Only laboratory tests are listed, for a list of biological indicators for grafting or mechanical inoculation see Stace-Smith (114). | | | | | | | | | |

For references see: Martin et al., 2013.

**Appendix Table 3.Top 15 *Rubus* accessions shipped between 1981 and 2015.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rank** | **Accession** | **Taxon** | **Plant name** | **Requested** | **Shipped** |
| 1. | [PI 553382](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553382&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus idaeus | Heritage | 106 | 101 |
| 2. | [PI 553457](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553457&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus idaeus | Goldenwest | 88 | 73 |
| 3. | [PI 553754](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553754&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus occidentalis | Black Knight | 86 | 64 |
| 4. | [PI 553322](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553322&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus hybrid | Chester Thornless | 80 | 72 |
| 5. | [PI 553740](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553740&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus occidentalis | Munger | 80 | 64 |
| 6. | [PI 553356](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553356&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus idaeus | Canby | 72 | 70 |
| 7. | [PI 553742](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553742&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus occidentalis | Jewel | 72 | 57 |
| 8. | [PI 553425](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553425&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus idaeus | Dormanred | 68 | 67 |
| 9. | [PI 553739](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553739&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus occidentalis | Cumberland | 68 | 51 |
| 10. | [CRUB 2690](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=2690&in_acp=CRUB&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus idaeus | Red raspberry D9-11 educational OP seed | 67 | 63 |
| 11. | [PI 553493](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553493&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus idaeus | Mandarin | 67 | 56 |
| 12. | [PI 553734](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553734&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus occidentalis | Black Hawk | 67 | 53 |
| 13. | [PI 553735](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553735&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus occidentalis | Bristol | 67 | 56 |
| 14. | [PI 553503](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553503&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus idaeus | Chilliwack | 65 | 58 |
| 15. | [PI 553247](https://sun.ars-grin.gov:8082/npgs/prodweb.accdisp.main?in_acno=553247&in_acp=PI&p_request=ID&oiflag=Y&ivflag=Y&obflag=Y&idflag=Y&imgflag=Y) | Rubus hybrid | Cherokee | 61 | 58 |