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# *Sorbus* sensu lato: A Complex Genus with Unfulfilled Crop Potential

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## Abstract

*Sorbus* a diverse genus in the *Malinae* subtribe of the *Rosaceae*, has multiple common names including mountain ash, rowan, whitebeam, and service tree. More than 600 species have been ascribed to *Sorbus*, yet recent phylogenetic studies indicate this polyphyletic group consists of multiple genera. *Sorbus* s.l. has a circumpolar boreal distribution with non-indigenous introductions of species in New Zealand and the US. Several genebanks of the US National Plant Germplasm System (NPGS) conserve representatives of 33 taxa within this diverse group. The Woody Landscape Plant Germplasm Repository (WLPGR) of the US National Arboretum maintains 85 active accessions as seeds and living plants in Washington DC, with a focus on wild species and intergeneric hybrids of ornamental and landscape value. The USDA ARS National Clonal Germplasm Repository (NCGR) in Corvallis, Oregon, maintains 38 *Sorbus* accessions with a focus on species with potential as fruit crops or rootstocks and 26 intergeneric accessions of *Sorbus* crossed with others of the *Malinae* subtribe. While *Sorbus* s.l. have been recognized for their ornamental qualities in the nursery and landscaping industries, this group also has potential for its edible fruit and use in processed products for the nutraceutical, juice, and brewing industries. Wild *Sorbus* s.l. species offer a great opportunity for breeding and selection of improved edible and ornamental cultivars. During the last century, the classical giants of fruit breeding, Luther Burbank (Santa Rosa and Sebastopol, California) and Ivan Vladimirovich Michurin (Tambov, Russia), bred and selected *Sorbus* s.l. The NCGR-Corvallis conserves eight Burbank selections and seedlings and seven Michurin releases, and is working to add additional accessions of their crosses. Building on Burbank and Michurin's breeding efforts, continued enhancement of wild plant material through controlled crosses could greatly improve flavor, reduce astringency, and enlarge fruit size for this crop. The possibilities of unique fruit development from intergeneric *Sorbus* s.l. crosses and backcrosses with other closely related genera is discussed. Expansion of the NPGS collections is planned to conserve additional species diversity. Germplasm in the NPGS system is available for research and can be requested from GRIN-Global.


"*Largely by chance, certain plants have come under the attention of man, and thus have been brought about the familiar fruits of our orchards, vineyards, and berry fields; who can predict the surprises with which the orchards and vineyards and berry fields of the next generation will reveal?*"

**Luther Burbank. 1914. His methods and discoveries 6(8):268.**

The US Department of Agriculture (USDA) Agricultural Research Service (ARS) US National Plant Germplasm System (NPGS) conserves germplasm of *Sorbus* sensu lato (s.l.) and closely related taxa in several genebanks across the country including the US National Arboretum (USNA) in Washington, DC, and the National Clonal Germplasm Repository in Corvallis, Oregon (NCGR-Corvallis). Germplasm in these genebanks are available for research purposes and can be requested from GRIN-Global (USDA, 2022).

The USNA was established in 1927 as an act of Congress to "establish and maintain a national arboretum for purposes of research and education concerning tree and plant life."

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**Figure 1.** Plant breeder, Luther Burbank, Santa Rosa, California, who selected *Cormus domestica* for their edible fruit.

Situated on 182 ha in northeast Washington, DC, the National Arboretum maintains diverse plant collections from around the world to fulfill research, conservation, and education objectives. In 1988, NPGS established a new genebank at the National Arboretum, the Woody Landscape Plant Germplasm Repository (WLPGR), which has grown to encompass both the National Arboretum campus as well as satellite research fields in Beltsville, Maryland. The WLPGR is responsible for over 200 genera of temperate trees, shrubs, and lianas, and collections are maintained as seeds and living plants. Ornamental and landscape plants are the primary focus of the WLPGR holdings, with special emphasis on documented wild-origin, rare and threatened taxa, and crop wild relatives. The National Arboretum maintains active plant exploration and research programs and is responsible for 678 official plant releases. Vouchers of wild-collected and cultivated plants are maintained in the National Aboretum's herbarium, which currently holds over 700,000 physical specimens.

The NCGR-Corvallis was established in 1981. Over the past 40 years, this genebank has conserved genetic resources of cultivars and crop wild relatives of many important temperate fruit and nut crops (Hummer and Postman, 2020; Postman et al., 2006). Within subtribe *Malinae* of the Rosaceae family, the NCGR-Corvallis maintains germplasm collections representing world diversity of pear (*Pyrus*), quince (*Cydonia*), and medlar (*Mespilus*), as well as smaller collections of juneberry (*Amelanchier*), chokeberry (*Aronia*), hawthorn (*Crataegus*), and mountain ash (*Sorbus*).

The objective of this article is to provide an overview of the conservation efforts and plant collections of *Sorbus* s.l. and its relatives within the NPGS. *Sorbus* s.l. breeding of the late 1800s and early 1900s by Luther Burbank (Fig. 1) and Ivan V. Michurin (Fig. 2) is also summarized. These two well-known and prolific plant breeders each produced new cultivars and selections of *Sorbus*, as well as a wide variety of plant species (Burbank, 1914; Michurin, 1949).

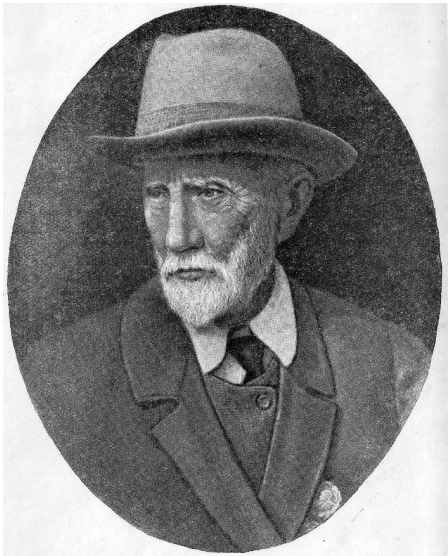

**Figure 2.** Russian plant breeder, Ivan V. Michurin, noted for his pome fruit selections for cold climates.

**Overview of *Sorbus* sensu lato**

*Sorbus* is a diverse and overlooked genus within the *Rosaceae*. In the broad sense (sensu lato, s.l.), this genus consists of about 250 species of trees and shrubs, which are native to temperate regions in Europe, Caucasia, North Africa, Turkey, North America, and parts of Asia (Aldasoro et al., 2004; Phipps et al., 1990; USDA, 2022). Many species are commonly known as "mountain ash" due to their pinnately compound leaves, though they are not related to ash (*Fraxinus*). Other common names for *Sorbus* s.l. include rowan (*S. aucuparia*), whitebeam (*Aria* species and hybrids), and service tree (C*ormus domestica*).

Spontaneous hybridization within and between species is common within wild populations. Robertson et al. (1991) noted that these interspecific crosses "reflect weak overall barriers to hybridizations rather than indicate evolutionary relationships" and suggested it was "best to discount intergeneric hybridization when setting generic limits." Robertson et al. (1991) went on to recommend that classification of the genus needed revision and suggested it be split into smaller genera based on morphological differences. Molecular studies have since demonstrated that *Sorbus* s.l. is not monophyletic, supporting separation and reclassification of the genus into multiple genera (Potter et al., 2007; Lo and Donoghue, 2012; Zika and Bailleul, 2014; Li et al., 2017; Sennikov and Kurtto, 2017). Based on continued taxonomic research (Robertson et al., 1991; Nelson-Jones et al., 2002; Robertson et al., 2010; Li et al., 2017; Hamston et al., 2018), *Sorbus* s.l. was split into multiple genera (USDA 2022), including the following: *Aria* [(Pers.) Host] (1831), *Chamaemespilus* [Medikus] (1789), *Cormus* [Spach] (1834), *Micromeles* [Decne.] (1874), *Sorbus* [L.] (1754), and *Torminalis* [Medik] (1789) (Phipps et al., 1990; Nelson-Jones et al., 2002; Aldasoro et al., 2004; Zika and Bailleul, 2014).

*Aria, Chamaemespilus*, and *Micromeles* have simple, unlobed leaves and pome fruit with heterogenous flesh (Lo and Donoghue, 2012). *Torminalis* have simple, palmately lobed leaves and represents a single species, *T. glaberrima* [(Gand.) Sennikov & Kurtto]. *Cormus* and *Sorbus* (strict sense) each have pinnately compound leaves. *Cormus* is another monotypic genus, represented by *C. domestica* [(L.) Spach] and morphologically separated from *Sorbus* sensu stricto (s.s.) due to its fused carpels. *Micromeles* was the product of ancient hybridization between the simple- and pinnate-leaved groups, as shown by chloroplast/nuclear incongruence (Lo and Donoghue, 2012). Recent hybridizations involving apomictic microspecies were also recognized within *Aria* and *Sorbus* s.s.

Some *Sorbus* s.l. species are diploid, e.g., *Aria edulis* [(Willd.) M. Roem.], *Torminalis glaberrima* [(Gand.) Sennikov & Kurtto], *S. aucuparia*, ×*Hedlundia thuringiaca* [(Nyman) Sennikov & Kurtto], *Chamaemespilus alpina* [(Mill.) K. R. Robertson & J. B. Phipps], and *Cormus domestica* [(L.) Spach]. Others are polyploid, mainly triploid (e.g., *Sorbus minima* (Ley) Hedl.) and tetraploid (e.g., *S. hybrida* [L.], *Sorbus microphylla* Wenz.) (Table 1). Polyploid species can often reproduce by apomixis, a process in which plants can produce seeds asexually that are genetically identical copies of the mother plant. Studies have demonstrated that apomixis in *Sorbus* s.l. is controlled by gametophytic apospory, in which the development of the embryo is dependent on pollination to initiate the formation of the endosperm (Robertson et al., 2010). Apomixis also contributes to some of the grouping and classification complexities mentioned above (Hamston et al., 2018).

*Sorbus* s.l. have intercrossed (some naturally, others in controlled crosses) with a number of other closely related genera, including hawthorn (*Crataegus*), medlar (*Mespilus*), serviceberry (*Amelanchier*), chokeberry (*Aronia*), apple (*Malus*), pear (*Pyrus*), and *Cotoneaster*. Many of these hybridizations can occur naturally if plants are growing in close proximity.

**Table 1.** *Sorbus* s.l. accessions in the USDA-ARS collections at the National Clonal Germplasm Repository, Corvallis, OR and the US National Arboretum sites in Washington DC and Beltsville, Maryland.

| Taxon | Former taxon | Name/Local number[z] | Accession | Ploidy[y] (x) | Origin/Source[x] |
|---|---|---|---|---|---|
| *Aria danubialis* (Jáv.) Sennikov & Kurtto | *Sorbus danubialis* | NA 82203 | NA 82203 | | Hungary |
| *Aria edulis* (Willd.) M. Roem. | *Sorbus aria* | WLP 1753 | PI 399408 | 2,3,4 | Slovenia |
| | | CSOR 117 | PI 652860 | | Uzbekistan, Tashkent |
| *Aria umbellata* (Desf.) Sennikov & Kurtto | *Sorbus umbellata* | CSOR 172 | PI 635929 | 2,4 | Hungary |
| | | NA 82204 | PI 635929 | | Hungary |
| | | NA 82205 | PI 635929 | | Hungary |
| *Cormus domestica* (L.) Spach | *Sorbus domestica* | CSOR 51 (Burbank) | PI 693298 | 2 | United States, California |
| | | CSOR 213 (Burbank) | PI 693411 | | United States, California |
| | | CSOR 215 (Burbank) | PI 693413 | | United States, California |
| | | CSOR 319 | PI 693430 | | Ukraine |
| | | CSOR 320 | PI 693431 | | Ukraine |
| | | CSOR 322 (Burbank) | PI 698280 | | United States, California |
| | | CSOR 321 (Burbank) | PI 698281 | | United States, California |
| | | CSOR 324 (Burbank) | PI 699310 | | United States, California |
| | | CSOR 329 (Burbank) | PI 700761 | | United States, California |
| | | CSOR 330 (Burbank) | PI 700762 | | United States, California |
| | | CSOR 331 (Burbank) | PI 700763 | | United States, California |
| *Micromeles alnifolia* (Siebold & Zucc.) Koehne | *Sorbus alnifolia* | WLP1771 | PI 635978 | 2 | China, Beijing Shi |
| | | CSOR 103 | PI 635909 | | United States, District of Columbia |
| | | CSOR 171 | PI 635928 | | United States, Minnesota |
| | | CSOR 242 | PI 635959 | | Estonia |
| | | NA 49501 | NA 49501 | | China, Hubei Sheng |
| | | NA 49502 | NA 49502 | | China, Hubei Sheng |
| | | NA 49504 | NA 49504 | | China, Hubei Sheng |
| | | NA 64218 | NA 64218 | | China, Heilongjiang Sheng |
| | | NA 72081 | NA 72081 | | China, Shaanxi Sheng |
| *Micromeles caloneura* Stapf | *Sorbus caloneura* | WLP 1881 | WLP 1881 | | China, Hubei Sheng |
| *Micromeles lanata* (D. Don) Mezhenskyj | *Sorbus lanata* | WLP 1824 | WLP 1824 | | Pakistan |
| | | WLP 1825 | WLP 1825 | | Pakistan |
| | | CSOR 60 | PI 635895 | | Pakistan |
| | | CSOR 61 | PI 635896 | | Pakistan |
| | | CSOR 62 | PI 635897 | | Pakistan |
| *Micromeles pallescens* (Rehder) Mezhenskyj | *Sorbus pallescens* | WLP 1872 | WLP 1872 | | China, Sichuan Sheng |
| *Sorbus americana* Marshall | | WLP 178 | WLP 178 | 2 | United States, Tennessee |
| *Sorbus aucuparia* L. | | CSOR 269 | PI 635088 | 2 | Ukraine, Kiev |
| | | CSOR 270 | PI 635089 | | Ukraine, Cherkasy |
| | | CSOR 43 | PI 635891 | | Uzbekistan, Tashkent |
| | | CSOR 45 | PI 635893 | | United States, Oregon |
| | | 'Moravskaya' | PI 635900 | | Lithuania |
| | | 'Cardinal Royal' | PI 635921 | | United States |
| | | CSOR 177 | PI 635932 | | United States, Washington |
| | | CSOR 178 | PI 635933 | | United States, Washington |
| | | CSOR 313 | PI 693425 | | United States, Oregon |
| | | 'Konzentra' | PI 693426 | | United States, Oregon |
| | | 'Russkaya' | PI 693427 | | United States, Oregon |
| | | 'Sunrise' | PI 693428 | | United States, Oregon |
| | | WLP 1754 | PI 407374 | | Croatia |
| | | WLP 1755 | PI 635893 | | United States, Oregon |
| | | WLP 1756 | PI 635894 | | United States, Oregon |

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|---|---|---|---|---|
| | WLP 1758 | PI 635895 | | Ukraine, Kiev |
| | WLP 1759 | PI 635896 | | Ukraine, Cherkasy |
| | WLP 1768 | PI 635897 | | Armenia |
| | WLP 1770 | PI 635898 | | Georgia |
| | WLP 1801 | WLP 1801 | | Georgia |
| | WLP 1830 | WLP 1830 | | Armenia |
| | WLP 1831 | WLP 1831 | | Armenia |
| | WLP 1852 | WLP 1852 | | Albania |
| | WLP 1857 | WLP 1857 | | Albania |
| *Sorbus aucuparia* subsp. *pohuashanensis* (Hance) McAll. | CSOR 169 | PI 635927 | 2 | Canada, Manitoba |
| | 'Rufa' | PI 635880 | | Japan, Hokkaidô |
| | WLP 1765 | PI 635960 | | China, Heilongjiang Sheng |
| | WLP 1766 | PI 635965 | | Russian Federation, Primorye |
| | WLP 1767 | PI 635966 | | Russian Federation, Primorye |
| | WLP 1772 | PI 635979 | | China, Beijing Shi |
| | WLP 1773 | PI 635981 | | China, Beijing Shi |
| | WLP 1775 | PI 635989 | | China, Shanxi Sheng |
| | WLP 1832 | WLP 1832 | | China, Beijing Shi |
| | WLP 1833 | PI 635977 | | China, Heilongjiang Sheng |
| *Sorbus aucuparia* subsp. *sibirica* (Hedl.) Krylov | WLP 1764 | PI 635956 | | Kazakhstan |
| | CSOR 40 | PI 635890 | | Uzbekistan, Tashkent |
| *Sorbus commixta* Hedl. | CSOR 114 | PI 635914 | 2 | United Kingdom, Scotland |
| | CSOR 116 | PI 635916 | | Korea, South |
| | CSOR 185 | PI 635938 | | United States, Washington |
| | CSOR 233 | PI 635955 | | United States, District of Columbia |
| | WLP 1779 | PI 369323 | | Russian Federation |
| | WLP 1845 | WLP 1845 | | Japan, Hokkaidô |
| | WLP 1846 | WLP 1846 | | Japan, Hokkaidô |
| | WLP 1847 | WLP 1847 | | Japan, Iwate |
| *Sorbus dacica* Borbás | CSOR 188 | PI 635940 | | Romania |
| *Sorbus discolor* (Maxim.) Maxim. | WLP 1774 | PI 635982 | 2 | China, Beijing Shi |
| | WLP 1804 | WLP 1804 | | China |
| *Sorbus esserteauana* Koehne | WLP 1783 | PI 635907 | 2 | Korea, South, Seoul-teukbyeolsi |
| | WLP 1786 | PI 635931 | | Korea, South |
| | 'Flava' | WLP 1817 | | Korea, South, Seoul-teukbyeolsi |
| *Sorbus foliolosa* (Wall.) Spach | CSOR 193 | PI 635942 | 2 | Nepal |
| *Sorbus hajastana* Gabrieljan | WLP 1799 | WLP 1799 | | Armenia, Geġark'unik' |
| | WLP 1834 | WLP 1834 | | Armenia |
| | WLP 1835 | WLP 1835 | | Armenia |
| *Sorbus hupehensis* C. K. Schneid. | WLP 1818 | WLP 1818 | 4 | United Kingdom, Scotland |
| *Sorbus hybrida* L. | CSOR 83 | PI 635904 | 4 | Lithuania |
| | CSOR 196 | PI 635945 | | United States, Washington |
| *Sorbus koehneana* C. K. Schneid. | WLP 1787 | PI 635983 | 2,4 | China, Shaanxi Sheng |
| | WLP 1823 | WLP 1823 | | United Kingdom, Scotland |
| *Sorbus matsumurana* (Makino) Koehne | WLP 1827 | WLP 1827 | 2 | United Kingdom, Scotland |
| *Sorbus meinichii* (Lindeb. Ex C. Hartm.) Hedl. | CSOR 197 | PI 635946 | | Norway |
| *Sorbus microphylla* Wenz. | WLP 1780 | PI 369324 | 4 | China |
| | WLP 1828 | WLP 1828 | | United States, Washington |
| | WLP 1837 | WLP 1837 | | Canada, Manitoba |
| *Sorbus minima* (Ley) Hedl. | CSOR 201 | PI 635949 | 3 | United States, Washington |
| | WLP 1838 | WLP 1838 | | United States, Washington |

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|---|---|---|---|---|---|
| *Sorbus randaiensis* (Hayata) Koidz. | | CSOR 203 | PI 635951 | | Taiwan |
| *Sorbus reflexipetala* Koehne | | WLP 1829 | WLP 1829 | | Uzbekistan, Tashkent |
| *Sorbus roopiana* Bordz. | | WLP 1839 | WLP 1839 | | Armenia |
| *Sorbus sambucifolia* (Cham. & Schltdl.) M. Roem. | | WLP 1776 | PI 652861 | 2 | United States, Alaska |
| | | WLP 1777 | PI 652862 | | United States, Alaska |
| | | WLP 1840 | PI 635953 | | United States, Alaska |
| | | WLP 1841 | PI 635968 | | Russian Federation, Habarovskij kraj |
| | | WLP 1849 | WLP 1849 | | Japan, Hokkaidô |
| *Sorbus sambucifolia* (Cham. & Schltdl.) M. Roem. var. *pseudogracilis* C. K. Schneid. | | WLP 1850 | WLP 1850 | | Japan, Hokkaidô |
| *Sorbus scalaris* Koehne | | CSOR 205 | PI 693301 | | China |
| *Sorbus scopulina* Greene | | WLP 1760 | PI 635882 | | United States, Wyoming |
| | | WLP 1761 | PI 635886 | | United States, Oregon |
| | | WLP 2414 | WLP 2414 | | United States, Utah |
| | | WLP 2415 | WLP 2415 | | United States, Utah |
| *Sorbus scopulina* Greene var. *cascadensis* (G. N. Jones) C. L. Hitchc. | | WLP 1762 | PI 635887 | | United States, Oregon |
| *Sorbus scopulina* var. *cascadensis* | | WLP 2338 | WLP 2338 | | United States |
| *Sorbus sitchensis* M. Roem. var. *grayi* (Wenz.) C. L. Hitchc. | | WLP 1763 | PI 635888 | | United States, Oregon |
| *Sorbus* sp. | | NA 75158 | NA 75158 | | China |
| *Sorbus tianschanica* Rupr. | | CSOR 163 | PI 635926 | | Canada, Manitoba |
| *Sorbus wilsoniana* C. K. Schneid. | | CSOR 135 | PI 635923 | 2 | United States |
| | | WLP 1871 | WLP 1871 | | China, Sichuan Sheng |
| | | WLP 1879 | WLP 1879 | | China |
| *Torminalis glaberrima* (Gand.) Sennikov & Kurtto | *Sorbus torminalis* | CSOR 120 | PI 635919 | 2,3 | Uzbekistan, Tashkent |
| | | CSOR 276 | PI 635972 | | Ukraine, Cherkasy |
| | | CSOR 274 | PI 635973 | | Ukraine, Kiev |
| | | CSOR 275 | PI 635974 | | Ukraine, Kiev |
| | | WLP 1842 | PI 635090 | | Ukraine, Vinnytsya |
| | | NA 85596 | NA 85596 | | Ukraine |

[z] Local numbers are assigned at individual repositories for in-house identification.
[y] Ploidy for species as reported in Nelson-Jones et al. ,2002; Aldasoro et al., 2004; Robertson et al., 2010; Pellicer et al., 2012; Li et al., 2017; Leitch et al., 2019.
[x] Origin/Source column provides information directly from GRIN-Global.

## Collections at US National Arboretum Woody Landscape Plant Germplasm Repository

The USNA WLPGR collection of *Sorbus* s.l. includes 85 accessions representing 35 taxa within four genera and two intergeneric hybrids (Tables 1 and 2). Representation by genus includes *Aria* (three species), *Micromeles* (four species), *Sorbus* s.s. (17 species, two subspecies, three varieties), and *Torminalis* (one species). The intergeneric hybrids ×*Tormaria latifolia* (*Aria* × *Torminalis*) and ×*Tormariosorbus intermedia* (*Aria* × *Sorbus* × *Torminalis*) are also represented with multiple accessions.

A subset of *Aria*, *Micromeles*, and *Torminalis* are maintained as living plants (13 individuals representing 10 accessions) within the USNA WLPGR living collections and research orchards. These simple-leaved genera have fared better in the Washington, DC, climate, which better approximates the heat and humidity for several of these east Asian taxa, particularly *Micromeles alnifolia*. Conversely, the compound-leaved *Sorbus* s.s. that are more cold adapted have historically

**Figure 3**. Diversity of *Sorbus* s.l. fruit at the USDA ARS National Clonal Germplasm Repository collection in Corvallis, Oregon. Photo credits: Ryan King, USDA, 21 July 2021.

struggled at the USNA, declining over time from environmental stress and pests such as spider mites. As a result, the majority of USNA WLPGR accessions including all *Sorbus* s.s. are maintained in seed storage at -20°C. Presently, 74 accessions representing 29 unique taxa are held in the seed bank and available via GRIN-Global.

### Collections at National Clonal Germplasm Repository-Corvallis

The NCGR-Corvallis *Sorbus* s.l. collection includes 50 accessions representing 17 *Sorbus* s.l. species (Table 1; Figure 3). Representation by genus includes *Aria* (two species), *Cormus* (one species), *Micromeles* (two species), *Sorbus* s.s. (11 species and two subspecies), and *Torminalis* (one species). The tree collection also includes 26 accessions of intergeneric crosses between *Sorbus* s.l. and *Amelanchier*, *Aronia*, *Pyrus*, and *Cotoneaster* (Table 2). Accessions are maintained as trees in orchards and greenhouses, and stored as seed in freezers at -20°C. Accessions are distributed as seeds or scions and available via GRIN-Global. Fire blight, caused by the bacteria *Erwinia amylvora*, is one of the primary maintenance challenges for *Sorbus* and other Rosaceous relatives in the Pacific Northwest and throughout the US. Many *Sorbus* s.l. species are susceptible to fire blight, and *S. aucuparia* and *S. americana* are noted as being highly susceptible (Hrdousek et al., 2014; Pscheidt and Ocamb, 2023). Other significant diseases include the following: *Pseudomonas* blossom blast (*Pseudomonas syringae* pv. *syringae*), powdery mildew, *Nectria* canker *(Nectria cinnabarina*), apple scab (*Venturia inaequalis*), *Cytospora* canker (*Cytospora* sp.)„ white rot *(Hapalopilus nidulans)*, and rusts (including *Gymnosporangium libocedri*). Insect pests are generally minor in the field collection at NCGR. Insect pests that can be problematic on *Sorbus* in the Northern US include root weevil, cherry bark tortrix (*Enarmonia formosana*), pear sawfly (*Pristophora abbreviate*), aphids (*Myzus* sp.), scale, and pearleaf blister mite (*Eriophyes pyri*) (Pscheidt and Ocamb, 2023).

### Ornamental uses

Many *Sorbus* s.l. species are valued and utilized as ornamentals due to their unique leaf morphology and fall color and for their large clusters of white flowers that mature into small, brightly colored fruits (Fig. 3), which are generally orange, red, yellow,

**Table 2.** *Sorbus* s.l. intergeneric crosses in the USDA-ARS collections at the National Clonal Germplasm Repository, Corvallis, OR and the US National Arboretum sites in Washington DC and Beltsville, Maryland.

| Taxon | Pedigree | Name/Local number[z] | Accession | Origin/Source |
|---|---|---|---|---|
| ×*Sorbopyrus* sp. | (*S. aucuparia* × *Pyrus*) × *S. aucuparia* var. *moravica* | 'Alaya Krupnaya' | PI 635957 | Estonia |
| ×*Sorbopyrus* sp. | *Sorbus* × *Pyrus* | 'Krasavitsa' | PI 635898 | Lithuania |
| ×*Amelasorbus jackii* Rehder | *Amelanchier alnifolia* × *S. scopulina* | CIGC 43 | CIGC 43 | United States, Idaho |
| ×*Sorbaronia dippelii* (Zabel) C. K. Schneid. | *Aria edulis* × *Aronia melanocarpa* | CIGC 23 | CIGC 23 | United States, Washington |
| ×*Sorbaronia fallax* (C. K. Schneid.) C. K. Schneid. | *S. aucuparia* × *Aronia melanocarpa* | CIGC 44 | CIGC 44 | United States, Massachusetts |
| | | 'Likyornaya' | PI 635899 | Lithuania |
| | | CIGC 45 | CIGC 45 | United States, Connecticut |
| | | CIGC 46 | CIGC 46 | United States, Massachusetts |
| ×*Sorbaronia sorbifolia* (Poir.) C. K. Schneid. | *S. americana* × *Aronia melanocarpa* | 'Stewart' | CIGC 16 | Canada, New Brunswick |
| | | 'Appleberry' | CIGC 17 | Canada, New Brunswick |
| ×*Sorbaronia* sp. | (*Aria edulis* × *Aronia arbutifolia* = *Sorbaronia alpina*) × *S. aucuparia* | 'Burka' | PI 635903 | Lithuania |
| ×*Sorbaronia* sp. | 'Burka' × *Malus/Pyrus* pollen mixture | 'Titan' | PI 693299 | Lithuania |
| × *Sorbocotoneaster pozdnjakovii* Pojark. | *S. sibirica* × *Cotoneaster melanocarpus* | CIGC 41 | CIGC 41 | United States, North Carolina |
| ×*Crataegosorbus* sp. | *S. aucuparia* × *Crataegus sanguinea* | 'Granatnaya' | PI 699312 | Russia, 1925 |
| ×*Sorbopyrus* sp. | *S. aucuparia* × *Pyrus communis* | 'Rubinavaya' | PI 635902 | Russia |
| ×*Sorbopyrus auricularis* (Knoop) C. K. Schneid. | *Pyrus communis* × *Aria edulis* | CIGC 28 | CIGC 28 | United Kingdom, England |
| | | 'Bulbiformis' | PI 318839 | Poland |
| | | 'Smokvarka' | PI 502176 | North Macedonia |
| | | 'Shipova' | PI 260199 | Former Serbia and Montenegro |
| ×*Sorbopyrus* sp. | | CIGC 42 | CIGC 42 | United States, Oregon |
| | | 'Baciu 1' | PI 506381 | |
| | | 'Baciu 2' | PI 506382 | |
| ×*Tormaria latifolia* (Lam.) Mezhenskyj | *Aria edulis* × *Torminalis glaberrima* | CSOR 118 | PI 635917 | Uzbekistan, Tashkent |
| | | CSOR 180 | PI 635935 | United States, Washington |
| | | CSOR 190 | PI 635941 | United Kingdom, England |
| | | WLP 1785 | PI 635917 | Uzbekistan, Tashkent |
| | | WLP 1826 | WLP 1826 | Uzbekistan, Tashkent |
| | | WLP 1836 | WLP 1836 | United States, Washington |
| ×*Tormariosorbus intermedia* (Ehrh.) J. M. H. Shaw | *S. aucuparia* × *Torminalis glaberrima* × *Aria edulis* | CSOR 179 | PI 635934 | United States, Washington |
| | | CSOR 198 | PI 635947 | United States, Washington |
| | | WLP 1781 | PI 399410 | Bosnia and Herzegovina |
| | | WLP 1819 | WLP 1819 | Uzbekistan, Tashkent |
| | | WLP 1820 | WLP 1820 | United States, Washington |
| | | WLP 1821 | WLP 1821 | Russian Federation |

[z] Local numbers are assigned at individual repositories for in-house identification.
[x] Origin/Source column provides information directly from GRIN-Global.

white, or pink (Table 3; Reich, 2004; Brenzel, 2012; Zika and Bailleul, 2014). *Hatch's Cultivars of Woody Plants* (2021) lists approximately one hundred twenty-five *Sorbus* s.l. named cultivars, including about thirty *S. aucuparia* cultivars. *Sorbus* s.l. species exhibit an array of forms and characteristics for many landscape uses (Table 3). Some species have a shrub habit (*S. americana*, *S. reducta*, *S. scopulina*) and others grow to be very large trees (*Aria edulis*, *Torminalis glaberrima*, *Micromeles alnifolia*, ×*Tormari-*

**Table 3.** Common *Sorbus* s.l. species that are used and recommended for their ornamental traits. Information adapted from *The New Sunset Western Garden Book* (Brenzel, 2012).

| Taxon | Common Name | Native Range | Habit | Zone[z] (*Sunset*) | Height/Width (m) | Fruit | Leaves |
|---|---|---|---|---|---|---|---|
| *Aria edulis* | whitebeam | Europe | tree | 3-10; 14-17 | 9-14/ 6-9 | red, orange-red | undivided, 5-10 cm long; dull green above, whitish beneath |
| *Micromeles alnifolia* | Korean mountain ash | China, Korea, Japan | tree | 1-10, 14-17 | 12-15 / 6-9 | reddish pink/ orange-red | undivided leaves: 5-10 cm long, toothed, dark green in color, turn yellow to orange in the fall |
| *Sorbus americana* | American mountain ash | Eastern US | tree/ shrub | 1-6 | 3-9/3-9 | orange-red | dark green leaves, pale underneath; reach 25.4 cm long; 11 to 17 leaflets |
| *Sorbus aucuparia* | European mountain ash | Europe to western Asia and Siberia | tree | A1-A3; 1-10; 14-17 | 6-12/ 4.5-7.5 | orange-red | 13-23 cm long, 9 to 15 leaflets; dull green above, gray-green below, turn yellow to reddish in fall |
| *Sorbus hupehensis* | Hubei rowan | Central/Western China | tree | 2-10;14-17 | 7.5/7.5 | white; pink-white | bluish green leaves to 18 cm long, 13 to 17 leaflets |
| *Sorbus hybrida* | oakleaf mountain ash | Norway, Sweden, Finland, Latvia | tree | 2-10;14-17 | 6-9/6-9 | red | 14 cm long, undivided, lobed upper portion, one or two small leaflets at base |
| *Sorbus reducta* | dwarf Chinese mountain ash | Western China | shrub | 3-6, 14-17 | .5 / 1 | pink | dark green, 10 cm long, 9 to 15 leaflets, bronze-red in fall |
| *Sorbus scopulina* | Western mountain ash | Western North America | shrub/ tree | A1-A3; 1-10; 14-17 | 1-4.5/ 1-4.5 | orange to bright red | 6.5 cm long with up to 15 deeply toothed leaflets; shiny dark-green above, paler underneath, orange-red fall color |
| ×*Hedlundia thuringiaca* | oakleaf mountain ash | Europe | tree | 3-6, 14-17 | 6-9/6-9 | red, smaller than *S. hybrida* | similar to *S. hybrida*, but leaves are longer (to 46 cm) |

[z] Sunset Climate Zones (found in *Sunset Western Garden Book*) are based on winter minimum temperatures, summer high temperatures, length of growing season, humidity, and rainfall, and do not correspond to USDA Hardiness Zones.

*osorbus intermedia*).

One of the most common species utilized in ornamental settings is the European mountain ash, *S. aucuparia*, which has pinnately compound leaves and large clusters of white flowers that mature into small (6-9 mm), showy red and orange pome fruits. *S. aucuparia* is very cold hardy, widely adaptable to many soils and climates, and tolerant of atmospheric pollution (Chalupa, 1992). The NCGR-Corvallis and USNA WLPGR collections include the cultivars 'Sunrise', 'Cardinal Royal', 'Moravskaya', 'Konzentra', 'Russkaya', and 'Rufa' among other accessions representing selections and wild species (Table 1). Other *Sorbus* s.l. species with potential as ornamentals include *Aria edulis, Cormus domestica*, *Micromeles alnifolia*, *S. americana, S. hupehensis*, *S. reducta*, *S. scopulina*, ×*Hedlundia thuringiaca* **(***Aria* × *Sorbus***)**, and *Torminalis glaberrima* (Table 3).

**Potential as a fruit and beverage crop**

Many species of *Sorbus* s.l. have edible fruit, but most are bitter and astringent due to high levels of tannins (Reich, 2004; Sarv et al., 2020). The fruits often require cooking or "bletting" before consumption. Bletting refers to a softening and ripening of the fruit following harvest (Reich, 2004). During this time of further ripening, sugar levels increase and acid and tannin levels decrease, making the fruit more palatable for fresh consumption. In many parts of Europe and Asia, *Sorbus* fruits are used in a wide variety of ciders, wines, liquors, and other processed products, such as juices, jams, and jellies (Sarv et al., 2020).

*Cormus domestica*, the service tree, has potential for fruit production. This species is native to southern and central Europe and has larger fruits than many other *Sorbus* s.l. Fruits, known as "sorbs" or "sorb apples", are 2-3 cm in diameter and resemble miniature apples or pears. *Cormus domestica* fruits have higher sugar levels and lower levels of starch and tanniferous cells than other species of *Sorbus* (Hrdousek et al., 2014; Sarv et al., 2020). Ripe, bletted fruits are eaten fresh and used in marmalades, wines, ciders, and liquors throughout the Czech Republic, Slovakia, Hungary, Austria, Germany, France, Luxembourg, Italy, and Spain (Hrdousek et al., 2014). A few examples include Cormé,

a traditional wine made from *C. domestica* in France and Switzerland, and Speierling, a German cider containing apples blended with *C. domestica* fruit. Hrdousek et al. (2014) provide a detailed review of *C. domestica* and its traditional uses (including its use for fruit and for its exceptionally hard wood in woodworking and early engineering), cultivation, fruit uses, and conservation.

*Micromeles lanata* is another species with potential for fruit production. Fruit are large (1-3 cm in diameter) and have much lower astringency than other *Sorbus* s.l., including *Cormus domestica*. This species was collected in Pakistan in 1988 by Dr. Maxine Thompson. PI 635895 is currently growing in the NCGR-Corvallis tree collection, and produces edible fruit every year. Other species with lower levels of tannins and potential as edible fruits include: *Aria edulis*, *S. americana*, *S. aucuparia*, *S. devoniensis*, *S. yuana*, *Torminalis glaberrima* (*S. torminalis*). It should be noted that some species (i.e. *Sorbus aucuparia*) contain parasorbic acid, a compound which can cause health issues if fruits are consumed in large quantities (Sarv et al., 2020). Harmful effects of parasorbic acid can be reduced by heating or freezing fruits (or harvesting after frosts), which causes the conversion of parasorbic acid to a nontoxic form, sorbic acid. Many of the cultivars developed for consumption have reduced levels of parasorbic acid (Sarv et al., 2020). Edibility could be greatly improved with breeding and hybridization with other species and genera—as Michurin did with *Sorbus aucuparia*, discussed further below (Reich, 2004; Zika and Bailleul, 2014; Sarv et al., 2020). 'Shipova', a cultivar of the intergeneric cross ×*Sorbopyrus auricularis* (*Pyrus communis* × *Aria edulis*), produces delicious fruits that are similar in flavor to pears. No fertile seeds are produced in this fruit as a result of the wide, intergeneric cross. In *Uncommon Fruits for Every Garden* (2004), Lee Reich describes the fruit of 'Shipova' as having a "buttery flesh– a bit more meaty than a pear– [that] melts with each bite to fill the mouth with semisolid, sweet and fragrant ambrosia."

**Nutritional and medicinal potential**

Due to their natural production of vitamins, carotenoids, phenolic acids and other important compounds beneficial to human nutrition, *Sorbus* have been evaluated for their nutraceutical and medicinal potential (Sarv et al., 2020). Sarv et al. (2020) presented a detailed review of the potential for *Sorbus* spp. in this context and suggested that *Sorbus* products could be an excellent source of absorbic acid and antioxidant compounds, including polyphenolics, i.e., proanthocyanidins, chlorogenic acid isomers, and flavonols. Sarv et al. (2020) and Moerman (2012) also documented the many traditional uses of *Sorbus* spp. bark, fruit, influorescenses, leaves, stems, and twigs for medicinal purposes. *Sorbus* spp. were used to treat a myriad of ailments and symptoms, including arteriosclerosis, asthma, constipation, chronic tracheitis, diabetes, dyspnoea, edema, gastritis, heart disease, kidney disease, neurological disorders, painful menstruation, scurvy, tuberculosis, and ventricular myocytes due to its antidiarrheal, anti-inflammatory, antinausea, antipyretic, antitussive, appetite improving, diuretic, emmenagogue, laxative, vasorelaxant, vasodilatory properties.

**Rootstock and potential**

*Sorbus* also has potential as a cold-hardy dwarfing rootstock for pears (Westwood, 1966; Postman, 1994; Elkins et al., 2012). Joseph Postman, former pear curator at NCGR-Corvallis, tested a number of intergeneric rootstocks and their compatibility with pears (Postman, 1994). Among the rootstocks he tested, *Micromeles alnifolia* and *Sorbus aucupari*a showed high compatibility with *Pyrus* (Personal communication). ×*Sorbopyrus auricularis* was tested as an interstem on *Pyrus* rootstock and also showed high compatibility. None of the pears grafted on *S. pohuashanensis,* however were successful. In grafting *Sorbus* s.l. species to other *Sorbus*,

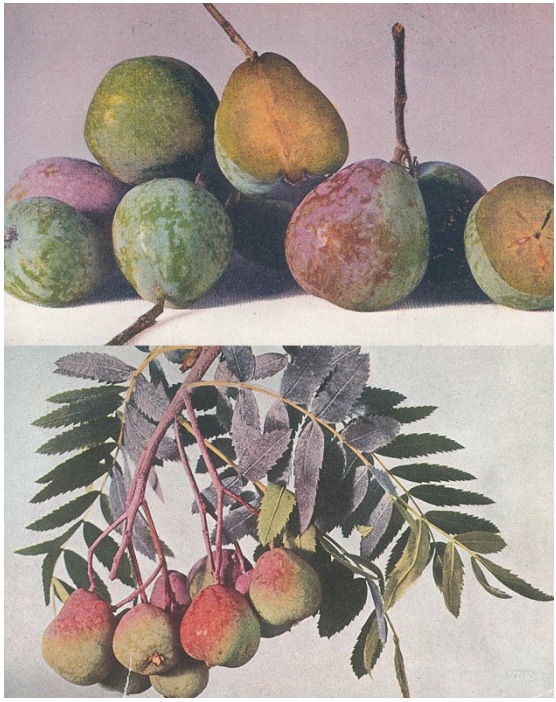

**Figure 4.** Fruit and leaves of Burbank's *Cormus domestica* selections in *Luther Burbank: His Methods and Discoveries* Volume VI(8):297,301

there does seem to be compatibility issues between species. For example, *Cormus domestica* scion or buds generally have higher survival when grafted to *C. domestica* rootstocks, and do not generally survive well on other Sorbus s.l., *Pyrus*, *Cydonia*, or *Mespilus*, even if the initial graft union is successful. There have been occasional reports of it surviving well on *Crataegus laevigata* and *Cydonia oblonga* (Hrdousek et al., 2014). At the NCGR-Corvallis, grafting success rate has been higher when grafting *Sorbus* scion to matching species (Personal conversations/notes from Joseph Postman, Jane Olsen, Jim Gilbert and Lorraine Gradener).

### Breeding with *Sorbus*

Despite its processed uses particularly in parts of Europe and Asia, *Sorbus* has been a neglected and under-developed horticultural crop in the US. This genus provides opportunities for selection and breeding of improved cultivars for ornamental and edible purposes. With the wide variation in forms, leaves, fruits and striking leaf and fruit colors, as well as ease of intergeneric hybridization, *Sorbus* has significant potential as an ornamental tree. Dual purpose cultivars could be developed that are suitable as ornamentals with edible fruit. Cultivars could be developed for fresh fruit uses by selecting for lower astringency, improved texture, and larger fruit. New cultivars could also be developed for nutraceutical and medicinal uses, as well as the cider and wine markets. Resistance to heat stress and important diseases (fire blight, powdery mildew, *Pseudomonas*) may also be important for new cultivars. Further intergeneric hybridizations amongst Sorbus s.l. genera and with *Pyrus*, *Crataegus*, *Aro-*


**Figure 5.** Fruit and leaves of Burbank's *Cormus domestica* selections: A) PI 693411, B) PI 693413, C and D) PI 693298. Photo credit: Ryan King, USDA, 29 October 2021.

*nia*, *Malus* and other close relatives could be explored and utilized to bring in desirable traits and expand the genepools of each of these genera.

The first high-quality complete genome assembly was recently reported in *Sorbus pohuashanensis*, a tree that is widely distributed in North, Northwest, and Northeast China (Zhao et al., 2022). Phylogenetic analyses of sequence data from 22 *Sorbus* s.l. taxa representing 11 species separated them into two groups based on leaf shape (simple vs. compound leaves). Pei et al. (2021) identified several genes linked to heat stress responses in *S. pohuashanensis*. Zhao et al. (2022) identified 33 candidate genes linked to tolerance of abiotic stresses, including differentially expressed genes involved in sunburn, a serious problem that can affect many tissues in various crops including pear (Goodwin et al., 2018), loquat and apple (Racsko and Schrader, 2012). Sunburn affects leaves, fruits and branches and is not desirable in ornamental or horticultural crops. These and future genomic resources will allow identification of genetic variation and genes related to traits of importance for producing and breeding *Sorbus* species.

**Table 4.** Notes and data on Burbank's *Cormus domestica* trees from Mark Albert and Todd Kennedy, who collected and donated scions to NCGR-Corvallis from Burbank's Gold Ridge Farms in 1992.

| Selection | Accession (PI) | Maturity | Fruit weight (g) | Fruit dimensions (height x width, cm) | Notes |
|---|---|---|---|---|---|
| A | 693409 | Early | 20-26 | 3.2 x 3.2 | Good quality. Pear shaped. Less russetting than others. Small, tight calyx. Fruit red-streaked on greenish yellow. Tree short and spreading. Probably a grafted clone from Europe. |
| B | 693410 | Early | - | 3.2 x 2.3 (dried) | As good or better quality than A. Largest tree. Pear shaped fruit. |
| C | 693411 | Mid-season | 30-32 | 3.5 x 3.9 | Good quality, yellow, largest fruit, larger and better looking than Dl; calyx 8 mm diameter. |
| D | 693412 | Mid-season | 23-27 | 3.3 x 3.4 | Better quality than C, a little smaller, more russetted, and greener in color. |
| E | 693413 | Late season | 17-22 | 3.1 x 3 | Unknown quality. Beautiful red-blushed green fruit, smaller than C. |
| F | 693414 | Mid-season | 17-19 | 3 x 2.8 | Small in size, red cheek on yellow smooth skin, and the most pear shaped. Calyx smaller than others except A, quality unknown. |

### The work of Luther Burbank

The well-known plant breeder Luther Burbank (1849-1926) bred and selected from *Cormus domestica* (formerly *Sorbus domestica*). In his *Methods and Discoveries,* Burbank (1914) suggests that he "greatly improved the size and beauty of the clusters of fruit." Little is discussed beyond this statement about his selections, and he never released any *Sorbus* cultivars. His book includes images of the range of fruit sizes of *Sorbus* species in comparison with his *Cormus* selections (Fig. 4). He stated, "the work of developing this fruit has only made the barest beginnings" (Burbank, 1914). Many of the trees he worked with and selected are growing on his properties at Gold Ridge Experiment Farm, in Sebastopol, California, and the Luther Burbank Home and Gardens in Santa Rosa, California. The NCGR-Corvallis is maintaining many of Burbank's *Cormus domestica* selections. Open pollinated seed (PI 693298) from one of Mr. Burbank's selections at Gold Ridge Farms was received in 1987. Seedlings from this lot have the largest and sweetest fruit amongst the *Cormus domestica* trees in the NCGR collection (Fig. 5). In 1992, Mark Albert, a fruit breeder and grower involved with the California Rare Fruit Growers, collected and sent scions from six of Burbank's selections from Gold Ridge Farms to the NCGR-Corvallis for preservation along with detailed notes that he and fellow fruit enthusiast Todd Kennedy collected about them (Table 4; Fig. 5). Of these six selections, two (PI 693411 and PI 693413) have survived and are currently growing in the collection. In 2021 and 2022, Rachel Spaeth at Luther Burbank Home and Gardens (Santa Rosa, CA) and volunteers at Gold Ridge Farms (Sebastopol, CA) coordinated new donations of scion from the *C. domestica* trees still growing at these locations, and the following accessions were added to the collection: PI 698280, PI 698281, PI699310, PI 700761, PI 700762, and PI 700763 (Table 1).

### The work of Ivan V. Michurin

Ivan V. Michurin (1855-1935), a Burbank contemporary, studied *Sorbus* in the Soviet Union. One of his major breeding goals was to transform wild plants into cultivars that were naturally productive, bore fruit every year, and were winter hardy during severe freezes. He saw *Sorbus*, *Crataegus*, and *Prunus* as fitting these criteria and successfully devel-

**Table 5.** *Sorbus* s.l. cultivars released by Ivan V. Michurin and his long time assistant A.S. Tikhonova, with notes from *Michurin's Selected Works,* Sokolov et al. (2015), and Goncharov and Savel'ev (2016).

| Cultivar | Pedigree | Accession (PI) | Inventory (CSOR/ CIGC) | Notes |
|---|---|---|---|---|
| Likornaya | *S. aucuparia* L. × *Aronia melanocarpa* (Michx.) Elliott. | 635899 | 75 | Resistant to severe frosts. Black, sweet fruit. Makes good preserves, cordials, liqueurs. |
| Burka | *Sorbus* × *alpina* (Willd.)Heynh. × *S. aucuparia* | 635930 | 80 | Fruit twice size of *S. aucuparia*, reddish-brown color, sweet tasting, "extraordinary" resistance to severe frosts. |
| Granatnaya' "pomegranate" | *Sorbus aucuparia* × *Crataegus sanguinea* Pall. | | 5 | Cross made in 1925. Seeds sprouted in 1926. First fruit in 1930 (five years of growth). Tree medium height. Unpaired leaflets. Fruit size of cherry, ribbed shape, sweet, sour taste without bitterness, useful for confectionary trade. Produces abundant crop and resistant to severe frosts. "Branches bear very beautiful and striking clusters of fruit the colour of pomegranate, that is why I named this mountain ash Granatnaya". |
| Dessertnaya, "dessert" | 'Likyornaya' × *Mespilus germanica* L. | N/A | N/A | Cross in 1926. Seeds sprouted in 1927. First fruit in 1931. Fruit is medium size, red in colour, similar to medlar shape, calyx has wide-open radially disposed interstices. Fruit are of sweet flavor, slight touch of bitterness of the ashberry that give it peculiar, subtle, piquant flavor. As regards flavor, this variety of mountain ash is so far the best I ever raised. "Masterpiece mountain ash." Low growing tree and very hardy to severe frost. |
| Chernoplodnaya, "chokeberry" | *Sorbus melanocarpa* (Michx.) Heynh. | N/A | N/A | Fully resistant to severe winter frosts. Black fruit of fine sweet flavor. Dwarfish height (under one meter). Can be used in preserves, jam. |
| Krasavitsa | *Sorbus* × *Pyrus* | 635898 | 72 | Released by long-time assistant, A.S. Tikhonova. |
| Alaya Krupnaya | (*Sorbus aucuparia* L. × pear mixture pollen) × *S. aucuparia* var. *moravica* | 635957 | 239 | Large orange-red fruit; Registered in 1999. |
| Rubynovaya | *Sorbus aucuparia* L. × pear mixture pollen | 635902 | 78 | Released by long-time assistant, A.S. Tikhonova; Light red fruit; Registered in 1999. |
| Titan | 'Burka' × apple and pear mixture pollen | 693299 | 73 | Dark red fruit; Registered in 1999. |

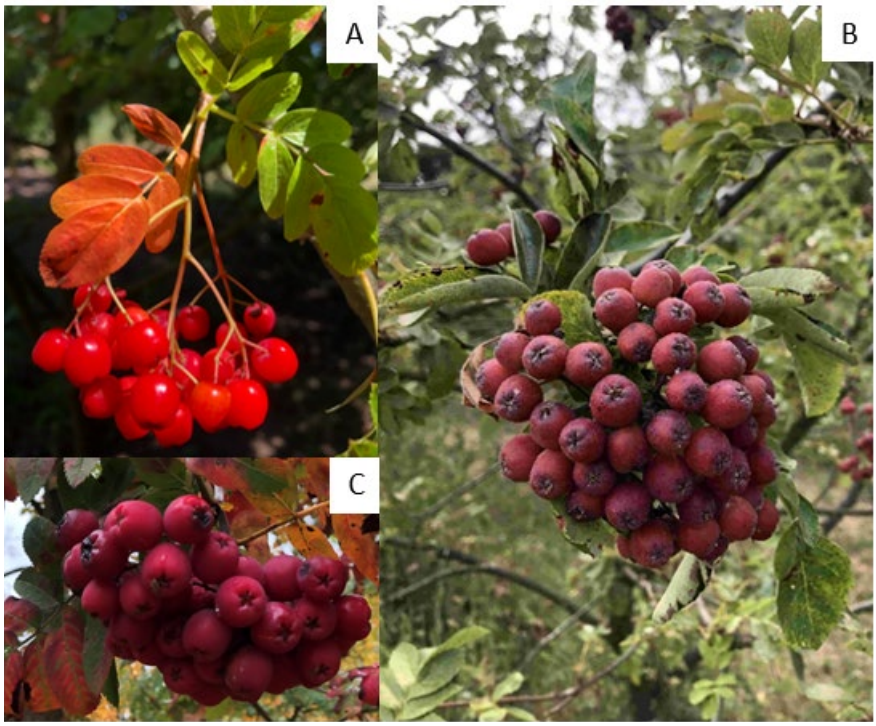


**Figure 6.** Ripe fruit from Michurin's cultivars: A) 'Rubinovaya' (PI 635902), B) 'Burka' (PI 635903), C)'Granatnaya' (PI 699312) Photo credit: Ryan King, USDA, 5 August, 2021.

oped many cultivars in each of these genera. Michurin was able to facilitate crosses among species and genera that were unable to naturally cross through sexual hybridization. One of the methods that he developed for overcoming these barriers is "vegetative rapprochement," in which he grafted species or genera to each other and then crossed to the scion years after the successful graft union was formed (Sokolov, 2015). Michurin wrote "this operation is much more likely to succeed in such cases, because by the time the crossing is performed the plants have developed a mutual affinity in their vital functions" (Michurin, 1949). Using vegetative rapprochement, Michurin was able to cross "apple with pear, *Amygdalus* [almond] with plum, *Amygdalus* with peach, apricot with plum, bird cherry with sour cherry, mountain ash with pear, apple with hawthorn, and quince with pear." He suggests that by using this technique, "an infinite prospect opens here for the possibility of obtaining entirely new species of fruit plants with unprecedented forms and properties" (Michurin, 1949).

Michurin noted the wide array of potential quality traits available in *Sorbus*. "Fruit breeders both here in our Union and abroad have paid absolutely no attention to the improvement of mountain ash varieties" (Michurin, 1949). He made numerous improvements in *Sorbus* and released several cultivars. In a recent study, Michurin's hybrids were noted to have large, dark fruits with lower astringency and exceptionally high levels of antioxidants and polyphenolics, compared to other *S. aucuparia,* which is likely due to having *Aronia* in their pedi-

gree (Sarv et al., 2021). Michurin took meticulous notes on his work with *Sorbus* and many of his other projects, many of which can be found in his *Selected Works* (1949). Details on the cultivars he released are noted (Table 5). Michurin's cultivars 'Burka', 'Rubinavaya', 'Krasavitsa', 'Likyornaya', 'Titan', and 'Granatanaya' were collected from the Kanus Botanical Institute in Lithuania by Tom Plocher of Minnesota and donated to the NCGR-Corvallis in 1989. 'Alaya Krupnaya' was collected in Estonia and donated to the NCGR-Corvallis in 1996. Fruits of Michurin's cultivars have been evaluated and images are uploaded to GRIN-Global (Fig. 6; USDA, 2022).

## Conclusions

*Sorbus* and its close relatives offer significant diversity for use as ornamental trees in the landscape as well as applications for food, medicine, and beverages. Although numerous *Sorbus* s.l. taxa have been improved by breeders for more than a century, there is great potential to develop novel selections through continued breeding and selection efforts.

Conservation of *Sorbus* s.l. and crop relatives is ongoing at the NPGS in multiple genebanks. Nearly half of the *Sorbus* s.l. species listed on the International Union for Conservation of Nature and Natural Resources (IUCN) red list (2023) are considered endangered (22.3%) or critically endangered (27.7%), and these species should be prioritized for conservation efforts. Within NPGS, heritage cultivars and selections along with wild species are maintained as orchard trees and as seeds held in cold storage. These accessions are available via GRIN-Global for continued research, breeding, and conservation purposes. Plans for expanding the collection to represent a broader array of heritage cultivars and selections as well as species are underway. Limited dormant scion wood cuttings and seeds are available seasonally for plant distribution requests for research.

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