USDA *Vaccinium* Crop Vulnerability Statement FY 2018
Part 2: Cranberries
Small Fruit Crop Germplasm Committee

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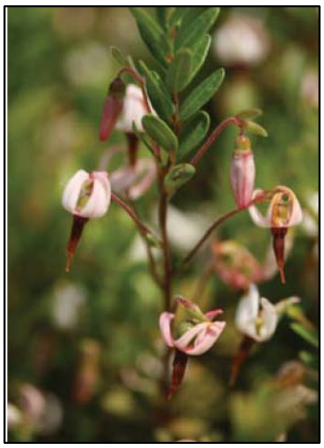


The large cranberry, *Vaccinium macrocarpon* Aiton, flowers (Wisconsin) and fruit being harvested.

The little leaf cranberry *Vaccinium oxycoccos* L. flowers and habitat in Hokkaido, Japan.

Executive Summary

Cranberries, *Vaccinium macrocarpon* Aiton, are native to North America. The U.S. is the world's largest producer with Canada and Chile also producing significant quantities. The top producing states are Wisconsin, Massachusetts, New Jersey, Washington, Oregon, and Maine. In 2016, production was 683.725 tons. The economic value of fresh and processed cranberry production in the U.S. is $3.55 billion annually and represents > 11,600 jobs. In Canada, the value is $411 million and includes > 2,700 jobs.

The desired fruit trait attributes of cranberry varieties has progressed over the last 100 years as the end products have changed. Initially high pectin content was a premium attribute for cranberry for sauce, followed by high anthocyanin content for juice drinks. Currently the main product is sweetend-dried-cranberry (SDC) for trail snacks. The fruit attributes for SDCs include homogeneous berry color, an anthocyanin color window, large fruit size (>2g/berry), and higher fruit firmness.

A broad genepool for genetic improvement exists at the national cranberry genebank which is located at the U.S. Department of Agriculture (USDA), Agricultural Research Service, National Clonal Germplasm Repository (NCGR) at Corvallis, Oregon. The genebank collection includes 81 *Vaccinium* taxa. The NCGR genebank contains 333 cranberry/crop wild relatives of cranberry (146 *V. macrocarpon*, 77 *V. oxycoccus*, and 110 *V. vitis- idaea*).

The NCGR genebank includes a primary collection of living plants and their crop wild relatives, grown in containers in protected enviroments such as screenhouses and greenhouses. Aphids, which vector viruses, are excluded from these houses. Integrated pest management techniques minimize key pests. A core collection representing world species and heritage cultivars has been defined. A secondary backup of the core collection is maintained *in vitro* under refrigeration. A long-term backup core collection of meristems and tissue culture plantlets was placed in cryogenic storage at the USDA ARS Plant and Animal Genetic Resources Preservation, Ft. Collins, Colorado. Wild species diversity is represented by seed lots stored at -18^{o} C. Plants at Corvallis are tested for common viruses, viroids, and phytoplasmas as resources allow but this testing may not completely meet the requirements of some foreign countries. 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. A set of single nucleotide polymorphism (SNP) markers for cultivar identification is under development.

The collection is documented for accession, inventory, voucher images, and morphological and genetic observations on the Germplasm Resources Information Network (GRIN-Global) in Beltsville, Maryland. More than 1,200 *V. macrocarpon* accessions have been distributed to international and domestic requestors during the past 25 years. In 2017, the collection had > 85 *V. macrocarpon* cultivars and 61 clones and 58 seedlots representing the wild species.

Other heritage cultivars and wild accessions unrepresented geographically are being sought to broaden cranberry diversity of the collection. Species are especially needed from northeastern North America including the Eastern US and Northeastern Canadian Maritime

Provinces; from the Appalacian Mountains; and from the Midwestern states, such as Minnesota, Michigan, and Wisconsin. During the past several decades, *in situ* conservation strategies have been initiated between the USDA and the U.S. Forest Service, as well as state heritage conservation programs in the Eastern U.S. American crop wild relatives of cranberry are prime candidates for *in situ/ex situ* conservation collaborations because of species distribution in many National Forests, state parks, and heritage sites from the Mid-western to the Eastern U.S.

1. Introduction to the crop

Cranberry and related wild crop species are classified as members of *Vaccinium* section *Oxycoccus* and section *Vitis-idaea*. Section *Oxycoccus* (which means "sour berry") includes plants that are perennial evergreen trailing woody vines. A second Section *Vitis-idaea*, includes the mountain cranberry, a circumboreal, evergreen, generally low-growing shrub, *V. vitis-idaea* L, and has been commercialized in Europe.

This statement will focus on Section *Oxycoccus* primarially, but will mention Section *Vitis-idaea* species as tertiary crop wild relative (CWR). The cultivated cranberry of commerce was the domestication ofthe American cranberry, *Vaccinium macrocarpon* Aiton, a native eastern North American species adapted to the temperate climate. Initially berries were collected from wild stands by native peoples; later, cultivation began with cuttings of elite native vines that were propagated in suitable moist 'boggy' soil locations. Genetic improvement was initiated in the 1930's by scientists at the USDA and New Jersey, Massachusetts, and Wisconsin Agricultural Experimient Stations in response to 'false-blossom' phytoplasma disease and production issues (Chandler et al. 1947). What was an exclusive U.S. and Canadian production has now become international with Chile, New Zealand, and Eastern Europe, now producing the cultivated cranberry.

1.1 Botanical features and ecogeographical distribution

Cranberry and blueberry are botanically classified in the genus *Vaccinum* L. which is in the blueberry tribe, *Vaccinieae*, of the subfamily *Vaccinioideae* of the *Ericaceae*, the heath family (Stevens, 1969). The *Vaccinieae* includes those *Vaccinioideae* plants that have inferior ovaries and have more or less fleshy fruits.

Vaccinium is polyphyletic as determined by DNA sequence data of the matK gene and nuclear ribosomal internally transcribed spacer (Kron et al, 2002). Thus, a global taxonomic reassessment of the definition of the genus is needed (Vander Kloet and Avery, 2010). Given that the taxonomy is controversial, this genus, as presently described, contains more than 400 species of vines, epiphytes, shrubs or small trees (Galletta and Ballington, 1996). Most of the described species occur in Malaysia, Southeast Asia, Japan, Africa, Europe, and South America (Vander Kloet, 1988), though about 30 species occur in North America. A number of the North American species have highly palatable fruit and several have been domesticated as commercial crops.

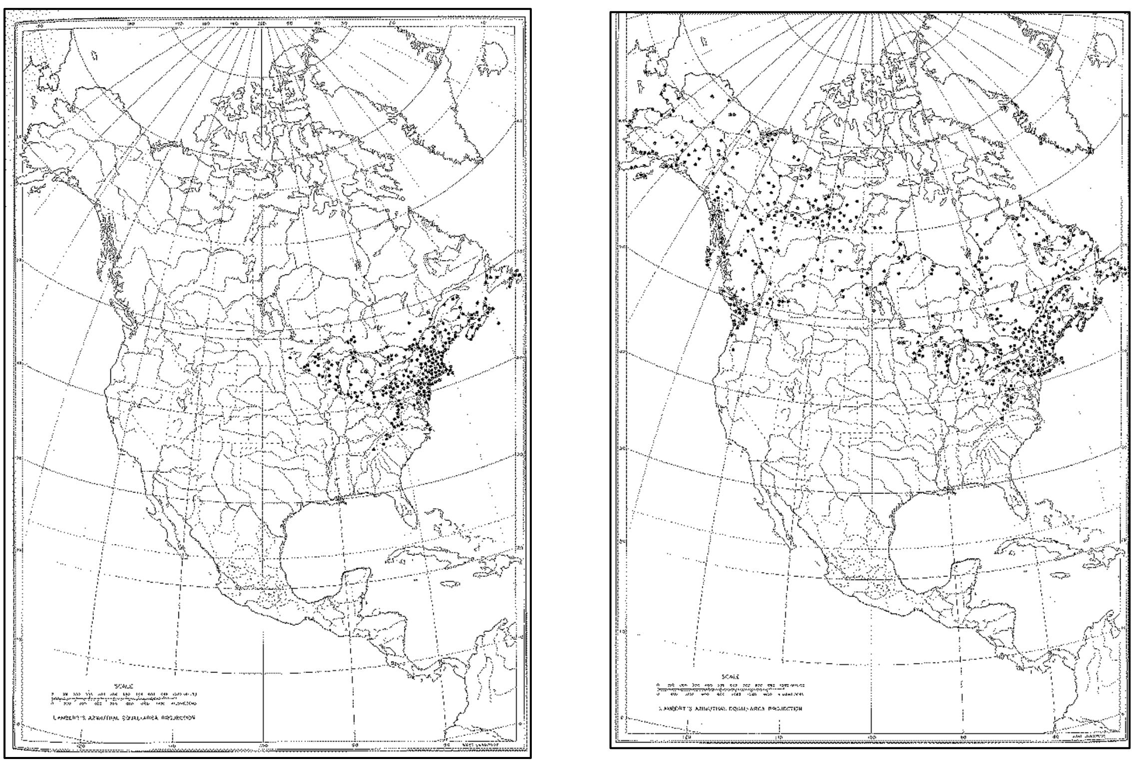
Vander Kloet (1988) described 10 North American sections within this genus. Character traits for blueberry and its closer relatives include 5-merous flowers, a generally fused urceolate corolla, and 5-celled (or pseudo10-celled) ovaries. [For more information on blueberry, please see the *Vaccinium* Vulnerability Statement, Part 1.] However, two sections of these North American *Vaccinium* have 4-merous flowers with 4-loculed ovaries. These are the cranberry and related wild species. Their information is presented here in *Vaccinium* Vulnerability Statement, Part 2.

Section *Oxycoccus*

This section contains two species: the large cranberry, *Vaccinium macrocarpon* Aiton, and the small cranberry, *Vaccinium oxycoccus* L.

The North American large cranberry is endemic to northeastern US and southestern Canada, while the small cranberry is circumpolar boreal in distribution and occurs broadly across northern North America (Fig. 1.1). The domesticated American cranberry is the species from which commercial cultivars have been selected and will be the focus of this vulnerability statement.

Fig. 1.1.1 Distribution of *Vaccinium macrocarpon* Aiton (left) and *Vaccinium oxycoccus* L. (right) from Vander Kloet (1988).



The large and small cranberries have corolla lobes that strongly reflex at anthesis. *V. macrocarpon* is diploid $2n = 2x = 24$ and *V. oxycoccus* members include diploids, tetraploids ($2n = 4x = 48$), and hexaploids ($2n = 6x = 72$) (Hummer et al. 2015). Diploid *V. oxycoccos* and *V. macrocarpon* are readily discriminated based on their allozymic variation and tetraploid *V. oxycoccos* appears to have an autopolyploid origin (Mahy et al. 2000). Autotetraploid *V. oxycoccos* may have undergone hybridization with *V. macrocarpon* or the autotetraploid retained the genetic variation present in an ancestral diploid species (Mahy et al. 2000). It has been suggested that *V. macrocarpon* is the more primitive species (Camp, 1944; Vander Kloet, 1988), however, the richer diversity of tetraploid *V. oxycoccos* suggests that an ancestral diploid species may be extinct. Intermittent co-migrations of these species following the onset of Pleistocene glaciation, and the occurrence of unreduced gametes in complex with parental isolation have been suggested as an evolutionary mechanism for the development of this ploidy series (Vander Kloet, 1988).

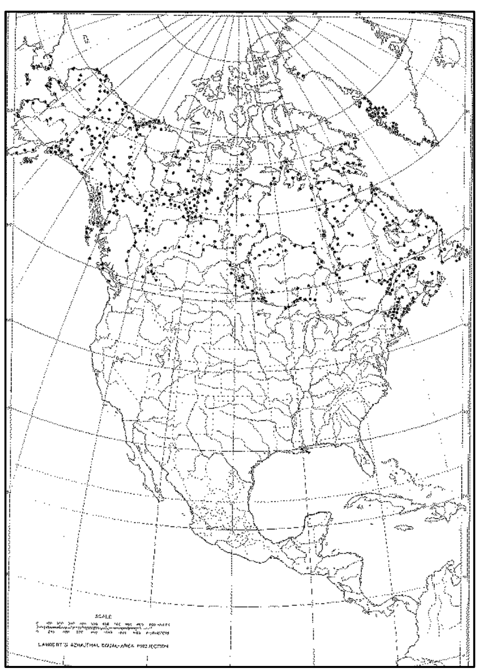
The domesticated cranberry of commerce is a trailing, low-growing, woody, evergreen vine. Stolons referred colloquially as runners, growing over 2 m in length, colonize the cranberry bed surface during early establishment. Over time these stolons, juvenile stems, form a dense mat to cover the bog surface, followed by production of a high density if fruiting vertical shoots. The flowers and fruit are borne on these vertical shoots referred to as "uprights." As a long-lived perennial commercial plantings can remain relatively productive for decades. Leaves normally remain on the plant for two seasons before they abscise. Leaves on subsequent shoots and stolons arising from previous years stems provide the photosynthetic source.

The small cranberry has an extensive record of casual use by Native Peoples throughout the north (Turner 1975; Moerman, 2009) and could be a potential secondary genepool for the cranberry of commerce.

Section *Vitis-idaea*

The mountain cranberry, *Vaccinium vitis-idaeus* L. is also known as "lingonberry." The mountain cranberry is circumpolar boreal in distribution and occurs broadly across North America (Fig. 2). The mountain cranberry has campanulate corollas with four small lobes. It is gathered from wild stands throughout Scandanavia, Europe and Russia, and is used commercially for processing into jams and jellies.

Fig. 1.1.2. Distribution of *Vaccinium vitis-idaea* L from Vander Kloet (1988).



1.2 Genetic base of crop production

The American cranberry was first developed as a crop of agricultural importance in North America in the late 1800s.

1. Cranberries – selections of *V. macrocarpon*, bred cultivars, propagated asexually by cuttings, with red skinned berries produced in cultivated bogs or fields.
2. Lingonberries – selections of *V. vitis-idaea*, primarially gathered from wild native stands in Scandanavia. Some breeding work has been done and some cultivars have been selected and grown under cultivation.

1.3 Economics of cranberries in the United States

Berries of native cranberry species are gathered from the wild in many locations throughout the Northern Hemisphere by indigenous peoples. The fruits were consumed fresh or processed into juices, jellies, jams, or frozen.

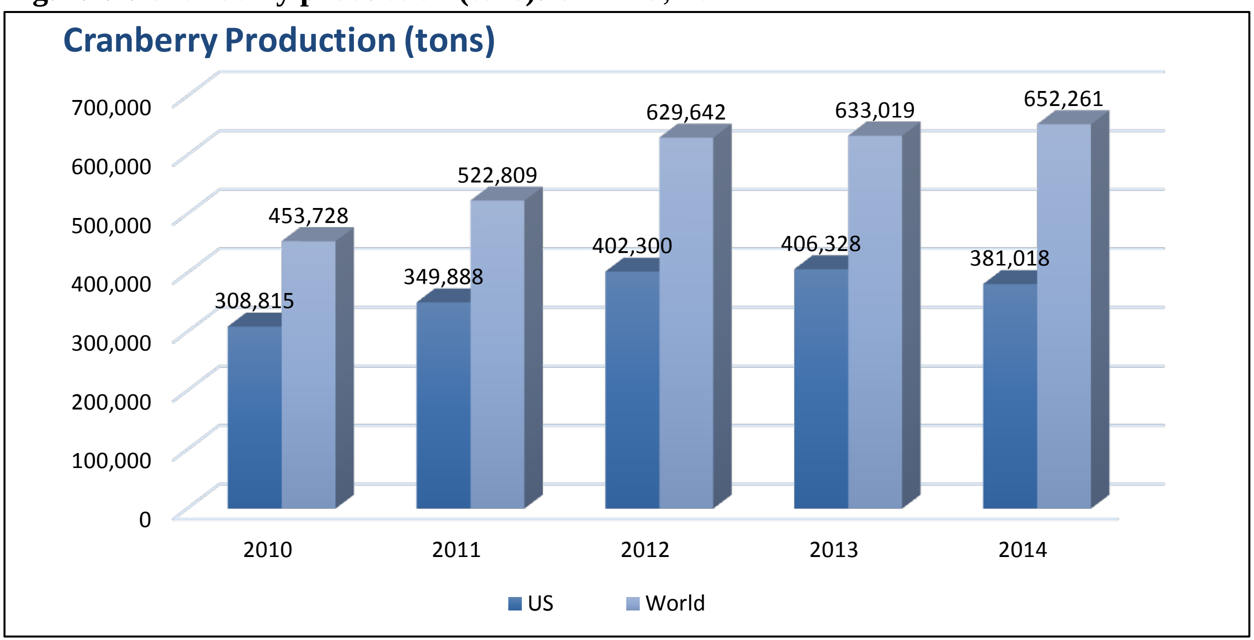
Cranberries are a moderately high value crop, particularly when sold as fresh fruit. The cranberry crop was worth $287,322,000 in 2013. The forecast for the 2016 crop is 8,412,700 barrels, up slightly from 2015. New Jersey's total production of 588,000 is close to last year's total. Massachusetts production was 2,070,000; Wisconsin production 5,209,700; Oregon 530,000 and Washington 194,000 barrels.
https://www.nass.usda.gov/Statistics_by_State/New_Jersey/Publications/Cranberry_Statistics/CRAN%20Aug_4pg.pdf; http://www.agmrc.org/commodities-products/fruits/cranberries

The USDA Cranberry Marketing Committee invoked its authority to implement a marketing order in 2000 and 2001 under which growers can only sell 85 and 65 percent of their sales history, respectively, to their handlers. USDA hoped that this stabilized prices to growers and, with aggressive generic marketing programs, eventually would allow grower prices to increase. Canada, which produces the bulk of cranberries imported into the U.S., has also instated a market allocation program. Cranberries are remaining in a state of US overproduction relative to demand, considering global commerce.

1.4. Domestic and international crop production

The total world cranberry production for 2014 was about 652,261 tons according to the UN FAO statistical agricultural database. In 2016, production was 683.725 tons according to the Cranberry Institute (2017). For the past 6 years, the U.S., Canada, and Chile were the largest cranberry producing countries in the world. Other countries that produce reportable amounts of cranberries include Belarus, Azurbaijan. Latvia, Romania, and Macedonia.

Fig. 1.4.1. Cranberry production (tons). UNFAO, 2017



http://www.fao.org/faostat/en/#data/QC accessed 08/08/2017

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UNFAO, 2017 Fig. 1.4.4 Cranberry production http://www.fao.org/faostat/en/#data/QC accessed 08/08/2017

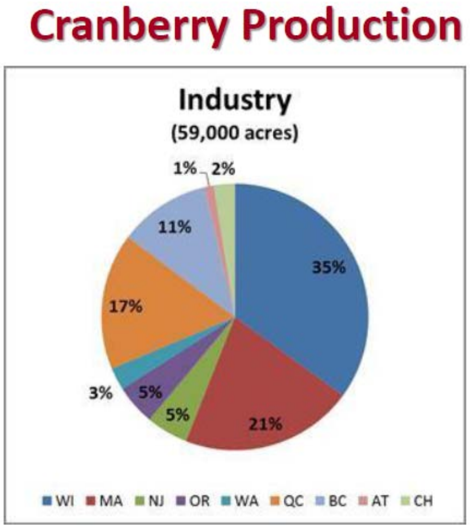

Fig.1.4.2. Global Cranberry Production (Cranberry Institute, 2017).

Economics and demand

The Cranberry Institute (2017) estimates that the economic value of cranberry production, fresh and processed, in the U.S. is $3.55 billion annually and represents > 11,600 jobs. In Canada, the value is $411 million and includes > 2,700 jobs. The industry encompasses 59,000 acres of cranberry production in the U.S in 5 states and 3 Canadian Provinces. In addition, Chile, in South America, produces about 2% of the total product

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Fig. 1.4.3. Cranberry production (by acreages) in U.S., Canada, and Chile

Year	United States	Canada	Chile	Total
2011	775,500	191,080	35,400	1,001,980
2012	793,700	295,400	35,480	1,124,580
2013	881,860	276,600	46,500	1,204,960
2014	805,780	337,300	40,800	1,183,880
2015	805,340	327,200	43,200	1,175,740
2016	922,760	395,890	48,800	1,367,450

Fig.1.4.4. Cranberry Area Harvested, Yield[z], Production, Price, and Value - States and United States: 2014-2016 [Net pounds per barrel: 100]

State	Area harvested			Yield per acre		
	2014	2015	2016	2014	2015	2016
	(acres)	(acres)	(acres)	(barrels)	(barrels)	(barrels)
Massachusetts	12,400	13,200	12,900	164.3	177.3	174.3
New Jersey	3,000	3,000	3,100	204.7	189.7	208.4
Oregon	2,900	2,900	2,800	162.8	191.4	140.7
Washington	1,600	1,600	1,600	97.5	123.8	109.4
Wisconsin	20,700	20,200	21,100	239.5	237.3	288.2
United States	40,600	40,900	41,500	202.9	206.7	230.0
State	Total production			Utilized production		
	2014	2015	2016	2014	2015	2016
	(barrels)	(barrels)	(barrels)	(barrels)	(barrels)	(barrels)
Massachusetts	2,070,000	2,352,000	2,268,000	2,037,000	2,340,000	2,248,000
New Jersey	652,000	595,000	653,000	614,000	569,000	646,000
Oregon	500,000	562,000	401,000	472,000	555,000	394,000
Washington	156,000	198,000	175,400	156,000	198,000	175,000
Wisconsin	5,022.000	4,856.000	6,130.000	4,957.000	4,793.000	6,081.00
United States	8,400,000	8,563,000	9,627,400	8,236,000	8,455,000	9,544,000
State	Area harvested			Yield per acre		
	2014	2015	2016	2014	2015	2016
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Massachusetts	37.10	32.80	30.70	75,523	76,783	68,911
New Jersey	36.90	37.70	43.10	22,657	21,445	27,835
Oregon	23.10	26.50	26.50	10,903	14,730	10,457
Washington	44.60	44.20	44.20	6,959	8,749	7,742
Wisconsin	27.90	29.20	29.20	138,370	140,146	177,347
United States	30.90	31.00	30.60	254,412	261,853	292,292

[z]Yield is based on utilized production

1.4.2 International

In Canada, cranberry production primarily occurs in Quebec, the Maritime Provinces, and British Columbia. Quebec's 2016 cranberry harvest reached almost 138 million tons (275.9 million pounds), a 32% increase compared to the 208 million pounds recorded in 2015. Quebec is now the second largest cranberry production region worldwide, behind Wisconsin.

Of the 276 million pounds, almost 247 million was harvested from the Centre-du-Quebec region, where almost 80% of Quebec's cranberry producers are based. In 2016, Quebec recorded 9,500 acres of cranberry production. The President of the Quebec Association of Cranberry Producers (APCQ), Louis-Michel Larocque, says that cranberry production has been recorded at an average of 29,000 pounds (290 barrels) per acre on Quebec farms. Quebec is the world leader in organic cranberry production. The sector saw a strong 87% increase in 2016 with harvest reaching 40.4 million pounds compared to the 21.6 million pounds recorded the previous year. Organic acreage will see a large increase over the next few years, and the APCQ says it will represents 31% of acreage put into production in 2018.

Chilean production of cranberry is on the increase. In 2016, it increased by 17%. In 2016, Chilean cranberry production increased to > 100,000 tons. Cranberry cultivation in Chile has reached 33,582 acres (13,590 hectares),

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

Cranberry, being a minor crop, lacks appropriate security propagation protocols for maintaining genetic fidelity, and official certification programs are not present. Primary collections at national genebanks consists of living plants, protected in containers in greenhouses or screenhouses, or growing in the field.

Plant material grown outdoors cannot be certified as pathogen negative. Secondary backup collections are maintained *in vitro* under refrigerated temperatures. Long-term backup collections of meristems are placed in cryogenic storage at remote locations to provide decades of security. Species diversity is represented by seed lots stored in -18°C or backed-up in tissue culture. Conservation of clonally propagated material, where genotypes were maintained, is more complicated and expensive than storing seeds, where the objective is to preserve genes. The health status of both forms of storage was of primary importance for plant distribution to meet global plant quarantine regulations.

Cranberry and lingonberry, being specialty crops, have limited world resources available for conservation of these crops and their wild relatives. These limited resources constrain the management of *Vaccinium* genetic resources. Pathogen testing and elimination procedures are critical to maintain pathogen-negative plants to satisfy quarantine requirements.

2.1 Genetic uniformity in the "standing crops" and varietal life spans

Cranberry cultivars were first selected from wild native stands roughly 160 years ago from the main growing regions of New Jersey, Maine, Michigan, Massachusetts, and Wisconsin in the U.S., and from Ontario, Quebec, and the Maritime Provinces in Canada. In the 1930s, a breeding program was initiated (Chandler et al. 1947), using those elite clones and selecting for productive types with desired pest resistance, e.g. blunt-nosed leaf hopper, phenological development, and desirable fruit quality. By 1983, more than 100 cultivars were named and described (Dana, 1983). However, the majority were wild selections and only seven hybrid cultivars resulting from a breeding and selection(s) were available at that time. Additional unnamed selections, e.g.#35, from the initial breeding program were maintained at Dubay Cranberries, WI, NJAES and MAES.

Active cranberry breeding programs include those at USDA, Rutgers University, University of Wisconsin, and private breeders. These programs have released cultivars that are highly improved for yield, fruit qualities, color intensity, fruit size, ripening season, storage attributes, and keeping quality (Vorsa and Johnson-Cicalese 2012). During the past two decades, growers began the transition from growing older heritage cultivars to those recently developed from breeding programs.

Fig. 2.2.1. Varietal life spans: Many of the earliest cultivars remain in production as of 2017.

Cultivar	Pedigree	Year	Origin
Early Black	Elite from wild	1835	Massachusetts
Howes	Elite from wild	1843	Massachusetts
McFarlin	Elite from wild	1874	Massachusetts
Searles	Elite from wild	1893	Wisconsin
Potters Favorite	Elite from wild	1895	Wisconsin
Prolific	Elite from wild	1900	Michigan
Ben Lear	Native Wisconsin	1901	Wisconsin
Franklin	Early Black x Howes	1930	Massachusetts
Stevens	McFarlin x Potters Favorite	1950	New Jersey
Beckwith	McFarlin x Early Black	1950	New Jersey
Wilcox	Howes x Searles	1950	New Jersey
Le Munyon	Elite from wild	1960	New Jersey
Pilgrim	McFarlin x Prolific	1961	Massachusetts
Bergman	Early Black x Searles	1961	New Jersey
Pilgrim	McFarlin x Prolific	1961	New Jersey
Crowley	McFarlin x Prolific	1961	New Jersey
Gryglesky Hybrid 1	Rezin x Searles	1982	Wisconsin
HyRed	Stevens x Ben Lear seedling #8	2003	Wisconsin
GH1	McFarlin x Searles	2004	Wisconsin
Crimson Queen	Stevens x Ben Lear	2006	New Jersey
DeMoranville	Franklin x Ben Lear	2006	New Jersey
Mullica Queen	(Howes x Searles) x LeMunyon	2006	New Jersey
Sundance	Stevens x Ben Lear	2011	Wisconsin
BG	Beckwith x GH 1	2012	Wisconsin
Scarlet Knight	Stevens x (Franklin x Ben Lear)	2012	Wisconsin

Cranberry selection and breeding

Cranberry cultivation first started in the 1800s with collections of wild selections of native *Vaccinium macrocarpon*. In 1810, Henry Hall, a Revolutionary War veteran from Dennis, Massachusetts, first cultivated the wild native cranberry (Eck 1990). Vines were selected based on fruit size, color, early ripening, and productivity. These vines were replanted in bogs or swamps in Massachusetts, New Jersey, and Wisconsin, and throughout the native range in the United States and Canada. As cultivated types achieved notoriety, they were given names according to the locality, land owner, or the shape of the fruit, e.g., ’Bell’, ’Bugle’, or ’Cherry’. ‘Early Black’, a cultivar selected in 1835, remains in cultivation to date (Vorsa and Johnson-Cicalese 2012).

The producing acreage in the early 1900’s of cranberry declined due to ‘false-blossom’ disease, a phytoplasma vectored by the blunt-nosed leaf-hopper. In response to ‘false-blossom’ disease in 1929 a cranberry breeding program was begun by the USDA in cooperation with the experiment stations at Massachusetts, New Jersey, and Wisconsin. C.S. Beckwith in New Jersey, H. F. Bergman in Massachusetts, and H. F. Bain in Wisconsin made the first crosses and selections for cranberry improvement through breeding. Seven first breeding and selection cycle generation artificial hybrid cultivars were released from 1950 to 1970, including ‘Beckwith’, ‘Bergman’, ‘Crowley’, ‘Franklin’, ‘Pilgrim’, ‘Stevens’, and ‘Wilcox’ (Eck 1990). Since then, 16 new proprietary cultivars have been released product from breeding programs at the University of Wisconsin-Madison, Rutgers University, and a private Wisconsin breeder (Valley Corp. http://www.cranberryvine.com/cranberry-varieties)

2.2 Threats of genetic erosion *in situ*

According to Natureserve (2017) *Vaccinium macrocarpon* has a secure species designation (G5). This species is widespread as a native plant in northeastern North America (Kartesz 1999), being found in acidic soils and peatlands including bogs, fens, swamps, and interdunal swales (Vander Kloet 1988, Weakley 2000). This species is rare in the portion of its range along the Appalachians and the Southeastern coastal plain (Weakley 2000).

2.3 Current and emerging biotic, abiotic, production, dietary, and accessibility threats and needs

Developing new cranberry cultivars requires breeders to be aware of existing and emerging needs throughout the supply chain, from producer to consumer and germplasm as source of critical breeding traits. Many diseases and pests challenge the growth and production of cranberry. Along with the US Department of Agriculture, and universities in the major cranberry production regions, the cranberry industry is a strong supporter of genetic enhancement efforts through research and breeding. Previously, organophosphates were mainly used to control insects in cranberry bogs or fields.

Recently as part of a USDA-NIFA SCRI planning grant entitled “Research and extension initiative for cranberry and blueberry: Current and future needs “A study was conducted to investigate the relative importance of cranberry producers’/processer preferences for fruit and plant quality traits. Industry responses, in general, signaled that the most important trait clusters were fruit quality, and in particular, firmness, fruit size and anthocyanin content. Among diseases, resistance to field fruit rot ranked the most important trait across all states. There were differences across states in importance assigned to other disease resistance traits, insect resistance and tolerance to abiotic stress (Gallardo et al. in preparation).

2.3.1 Biotic (diseases, pests)

Viral diseases

Four viruses that infect cranberries have been reported (Appendix Table 3). Martin et al. (2012) describe their vectors and epidemiology whereas McFarlane et al. (2015) provided information on detection methods, regional occurrence, and common primers (Appendix Table 4 and 5). Besided the viruses, a subgroup 16SrIII-V phytoplasma associated with false blossom significantly affects cranberry yield (Lee et al., 2014). The phytoplasma reduces plant growth and yield and has played a significant part in the development of cranberry cultivars (Caruso 2008).

False blossom disease, caused by a phytoplasma, is vectored by leaf hoppers. The disease has been a problem since cranberries first became cultivated in the early 1900s. The disease likely originated in Wisconsin but was transferred on planting material to New Jersey and Massachusetts. The disease had an impact on New Jersey cranberry production. But despite the disease issue, researchers observed differential resistance by cultivar. 'McFarlain' and 'Early Black' were resistant, 'Bennett Jumbo' and 'Vorse's Pride' had moderate infection, and 'Bell', 'Berlin', 'Centennial', 'Howes', 'Metallic Bell', 'Palmeter', 'Prolific', 'Searles', and 'Wales Henry' were susceptible. The resistance is hypothetically achieved due to the preference of the leaf hopper to tissue of the different cultivars.

Fungal and bacterial diseases

Cranberry plants and fruit are affected by a number of major fungal diseases including root rots caused by *Phytophthora cinnamomi*; diebacks caused by *Phomopsis vaccinia*, *Fusicoccum putrefaciens*, and *Synchronoblastia crypta*; and leaf spots caused by *Pyrenobotrys compacta* and *Protoventuria myrtilli*. Fruit rot is another major proble in all US cranberry growing regions. This disease is caused by a "disease complex" of 10 to 15 pathogenic fungal species, varying by year and location (Stiles and Oudemans 1999). In the survey mentioned above, among 10 diseases resitance triats, resitance to fruit rot was identified as the most important trait. Fungicides are the primary agents to target the fungal diseases, though integrated control strategies, such as improving drainage using tile, stones or installing ditches at the appropriate depth is essential. Sources of fruit rot resistance and QTLs have been identified.
http://journal.ashspublications.org/content/140/3/233.abstract
https://link.springer.com/article/10.1007/s11032-017-0639-3

Addition of sand and extra fertilizer can improve growth of stressed plants to stimulate root growth. Source of resistance to fruit rot has been indetified and used to identify quantitative trait loci (QTLs) associated with fruit rot disease resitance (Daverdin et al. 2017).

Insect and arthropod pests

Insect pests include the black-headed fireworm *Rhopobota naevana* (Hübner) Cranberry fruitworm (*Acrobasis vaccinii* Riley), Sparganothis fruitworm (*Sparganothis sulfureana* Clemens**)**, Cranberry weevils (*Anthonomus musculus* Say), cutworms, and green and brown span worm. Cranberry beds are monitored using a sweep net and integrated pest management strategies are applied according to the catch. Flooding of the bog, pheromones, mating disruption, and chemicals that interfere with insect growth stages are applied. In the early 1900s, the blunt-nosed leafhopper was an early challenge for the newly started New Jersey cranberry industry.

This leafhopper vectored the phytoplasma that caused “false-blossom” disease. Several US Departent of Agriculture entomologists noticed differential feeding by the insect on different cultivars. The first breeding program was established with the goal of developing cultivars with blunt-nosed leafhopper resistance. Based on field observations and feeding preferences, Wilcox and Beckwith (1933) reported that ‘Early Black’ and ‘McFarlin’ were not preferred as compared with ‘Howes’. The cultivars ‘Plum, and ‘Shaw’s Success’ were also most resistant, while Bergman, ‘Franklin’, ‘Pilgrim’ and ‘Wilcox’ were resistant (Dana 1983). To control this disease crosses were made using the resistant cultivars, to obtain resistant offspring. However a false-blossom’ resistant variety was not forth coming. It should be noted that as organo-phospahte insecticides are banned or restricted new insect threats have emerged, e.g., toad-bud, myriads, thrips.

In a 2017 survey, differences were observed in the importance of selected insect pest resistance traits. In New Jersey, respondents indicated that the most important pest resistance trait was for blunt-nose leafhoppers, whereas in Wisconsin cranberry fruit worm, and in British Columbia, cranberry tip worm.

2.3.2 Abiotic (environmental extremes, climate change)

Abiotic stresses are major environmental challenges that impact cranberry plant productivity. In the 2017 survey, North American cranberry production regions differed in the ranking of abiotic stress traits (Gallardo et al.). In New Jersey, heat stress was selected as the most important abiotic stress trait, while in Wisconsin and British Columbia fall and spring frost tolerance was most important.

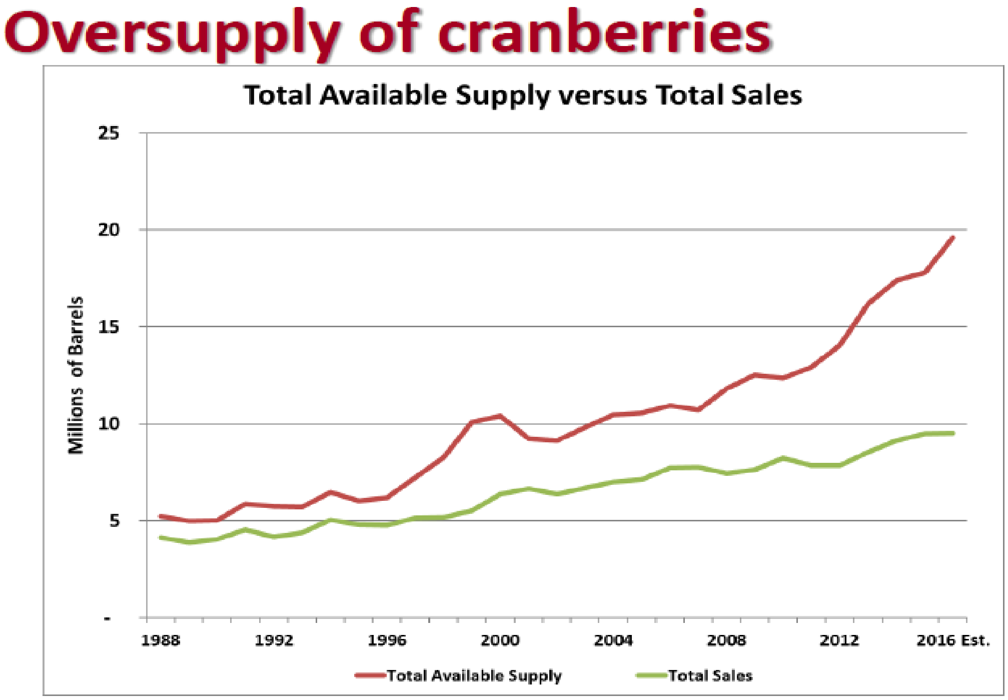
2.3.3 Production/demand (inability to meet market and population growth demands)

While cranberries used to be produced only for fresh use and sauces, then a product line of juices were developed. Higher amounts of fruit production encouraged innovative development of products. Cranberry product lines include juice, sweetened-dried-fruit, sauces, fresh fruit, nutraceutical powders, and other miscellaneous forms.

Processed cranberry product sales have been increasing over the past three decades and as of 2017 require > 9 million barrels of fruit. Unfortunately, over those decades there has been an increasing overproduction of fruit (oversupply) compared with the product sales (demand) which has kept price return for growers low.

As mentioned above, a renced breedind trait survey indicated that improving fruit quality is a primary need for cranberry industry. The most important fruit quality trait indetified in this survey were: fruit firmness, fruit size and color. These traits that can affect price premiums the grower receives, can positively drive consumer demand, and improve processing handling, which are all critical factors to the economic viability of the cranberry industry.

Fig. 2.3.3.1 Oversupply of cranberries. (Humfeld, 2017)



2.3.4 Dietary key nutritional requirements)

The North American cranberry has multiple health benefits linked to phytochemicals in the fruit. Cranberry juice is consumed for the prevention of urinary tract infections (Vorsa et al. 2002). This property is linked with the ability of proanthocyanidins to inhibit adhesion of uro-pathogenic P-fimbriated *E. coli* bacteria responsible for these infections.

Cranberry flavonoid extract has been shown to ameliorate metabolic syndrome molecular status, a precursor stage to diabetes II, through adiponectin modulation in a rat model (Shabrova et al 2012). Cranberry proanthocyanidins are active against dental caries *Streptococcus mutans* (Dongyeop et al. 2015, Koo et al. 2010). Additional studies have found that cranberry constituents also inhibit adhesion of a major cause of gastric cancer. Emerging evidence suggests that cranberry phytochemicals (particularly proanthocyanidins, quercetin, and ursolic acid) have a mitigating effect on other types of cancers as well and could be a dietary chemoprotective (Wang et al. 2015).

Fig. 2.3.4.1 Key Dietary nutritional compounds in cranberry

Nutrient	Unit	Value per 100 g
Proximates		
Water	g	87.32
Energy	kcal	46
Protein	g	0.46
Total Lipid (fat)	g	0.13
Carbohydrate, by difference	g	11.97
Fiber, total dietary	g	3.6
Sugars, total	g	4.27
Minerals		
Calcium, Ca	mg	8

Showing 33 nutrients
https://ndb.nal.usda.gov/ndb/foods/show/2191?fgcd=&manu=&lfacet=&format=&count=&max=50&offset=&sort=default&order=asc&qlookup=cranberries&ds=Standard+Reference&qt=&qp=&qa=&qn=&q=&ing=

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

Because cranberries are a North American native crop, access to plant genetic resources are direct. The primary species is not threatened or endangered for the most part. Phytosanitary or quarantine regulations are not an issue. Recently released cultivars are under US Plant Patents. As these patents expire the germplasm will become available to the domestic collections. Wild species and heritage cultivars are available and accessible to researchers and the public.

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

3.1 Germplasm collections and *in situ* reserves

The US national cranberry genebank collection is kept *ex situ* in Corvallis, Oregon. Back-up seed of species are maintained in freezers in Corvallis and have been sent to NCGRP in Ft. Collins, Colorado, and to the Global Seed Vault in Svalbard, Norway.

In situ reserve agreements have been established over the years in 5-year incriments for native cranberry in the Eastern United States working with the US National Forests (US Forest Service) and state heritage conservation programs. This crop would be a good candidate to consider for additional in situ conservation within the United States.

The USDA Agricultural Research Service and the US Forest Service (USFS) have joined forces to conserve CWR native to the US, specifically on lands in the National Forest System. The collaboration was formalized through an agreement between the agencies and further developed in The USFS-ARS Joint Strategic Framework on the Conservation and Use of Native Crop Wild Relatives in the United States, finalized in 2014. The foundation of the strategic framework is its emphasis on complementary conservation, with plants in living populations on National Forest Lands linked with germplasm conserved *ex situ* in genebanks of the NPGS. Two general approaches are established, one focusing on conserving the CWR of one specific crop, and the other on CWR of multiple crops within the boundaries of a specific protected area.

As a pilot study for the first approach to *in situ* conservation in the Framework, the USDA ARS Plant Exchange Office of the National Germplasm Resources Laboratory is collaborating with USFS botanists on the conservation of the wild relatives of cranberry; the large cranberry (*Vaccinium macrocarpon* Aiton) and the small cranberry (*Vaccinium oxycoccos* L.). Representative populations of these species across the species' native ranges in the US are being studied on National Forests. Standard protocols developed by the ARS and USFS are being used to collect leaf tissue for DNA analysis, collect fruit and seed, and prepare herbarium vouchers. Leaf tissue from all populations is sent to the ARS Cranberry Genetics and Genomics Laboratory in Madison, WI, for molecular analysis of inherent genetic variability.

Representative germplasm is maintained as seedlots and plants at the National Clonal Germplasm Repository in Corvallis, Oregon. Herbarium vouchers are maintained by the U.S. National Arboretum in D.C. The goal is to identify those populations that are the highest priority for designation as *In Situ* Genetic Resource Reserves (IGRRs). This designation will be based on location, distance from other populations, sustainability, population size, genetic profile, ease of access, and cultural significance to Native Americans. Long-term management plans will be implemented by the USFS to monitor, manage, and safeguard the security of the populations. In the future, expansion of the study to populations outside the National Forest System is planned to encompass broader genetic diversity of the two American wild cranberry species, *V. macrocarpon* and *V. oxycoccos*.

3.1.1 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 that 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 cranberry clonal collections at the NCGR-Corvallis is listed below. The list can be obtained by searching GRIN (GRIN-Global 2017) accession text query entering: "*Vaccinium* cultivar".

Fig. 3.1.1.1. Cranberry[z] collections held at the NCGR-Corvallis (GRIN-Global, 2017)

Accession	Inventory Number (CVAC)	Primary form	Backup form	Name	Origin
PI 618039	1026.001	PL		AA 4 Boone cranberry	United States, Wisconsin
PI 554979	492.001	PL	TC	AJ	United States, New Jersey
PI 618040	1027.001	PL	TC	AR 2 Boone cranberry	United States, Wisconsin
PI 618041	1028.001	PL	TC	Bain Favorite No. 1	United States, Wisconsin
PI 618051	1038.001	PL	TC	Bain Favorite No. 2	United States, Wisconsin
PI 618042	1029.001	PL		Bain 2	United States, Wisconsin
PI 618043	1030.001	PL		Bain 3	United States, Wisconsin
PI 618044	1031.001	PL		Bain 4	United States, Wisconsin
PI 618045	1032.001	PL		Bain 5	United States, Wisconsin
PI 618046	1033.001	PL		Bain 6	United States, Wisconsin
PI 618047	1034.001	PL		Bain 7	United States, Wisconsin
PI 618048	1035.001	PL		Bain 8	United States, Wisconsin
PI 618049	1036.001	PL		Bain 9	United States, Wisconsin
PI 618050	1037.001	PL		Bain 10	United States, Wisconsin
PI 618052	1039.001	PL		Bain McFarlin	United States, Wisconsin
PI 657266	1825.001	PL		BE 4 cranberry	United States, Washington
PI 554990	496.001	PL	TC	Beckwith	United States, Maryland
PI 554983	503.001	PL	TC	Ben Lear	United States, Wisconsin
PI 554973	112.002	PL		Bennett	United States, Wisconsin
PI 657166	1677.002	PL		Bennett - Floyd Brown's Bog - Bandon	United States, Oregon
PI 554982	662.002	PL	TC	Bergman	United States, New Jersey
PI 618053	1040.001	PL		Biron Selection	United States, Wisconsin
PI 555008	770.001	PL		Black Veil	United States, Massachusetts
PI 555024	827.001	PL	TC	Bugle: Mashpee type	United States, Massachusetts
PI 555023	826.001	PL		Bugle: Wareham type	United States, Massachusetts
PI 555009	771.001	PL	TC	Centennial	United States, Massachusetts
PI 554999	745.001	PL	TC	Centerville	United States, Massachusetts
PI 555000	746.001	PL	TC	Champion	United States, Massachusetts

PI 554980	493.001	PL	TC	Cropper	United States, New Jersey
PI 554976	111.001	PL	TC	Crowley	United States, Washington
PI 657167	1678.002	PL		Crowley - Floyd Brown - Bandon	United States, Oregon
PI 657170	1681.002	PL		Crowley - Ray Gardner - Bandon	United States, Oregon
PI 618054	1041.001	PL		Drever	United States, Wisconsin
PI 554986	741.002	PL	TC	Early Black	United States, Massachusetts
PI 555001	747.002	PL		Foxboro Howes	United States, Massachusetts
PI 554998	743.001	PL	TC	Franklin	United States, New Jersey
PI 555010	772.001	PL	TC	Garwood Bell	United States, New Jersey
PI 555011	773.001	PL	TC	Gebhardt Beauty	United States, Wisconsin
PI 638768	1447.001	PL		Grygleski 2	United States, Wisconsin
PI 618055	1042.001	PL		Habelman 2	United States, Wisconsin
PI 554995	708.002	PL		Hamilton	United States, Massachusetts
PI 618056	1043.001	PL		Hollison	United States, Massachusetts
PI 614076	1296.001	PL	TC	Howes	United States, Massachusetts
PI 554996	709.001	PL	TC	Langlois Form	United States, Oregon
PI 554985	499.001 TC	TC	TC	Le Munyon	United States, Wisconsin
PI 618057	1044.002	PL		Matthews	United States, Massachusetts
PI 614075	1295.001	PL	TC	McFarlin	United States, Massachusetts
PI 657165	1676.002	PL		McFarlin - Frasier - Bandon	United States, Oregon
PI 618058	1045.001	PL		Middleboro	United States, Massachusetts
PI 554978	491.001	PL	TC	No. 35 (cranberry)	United States, New Jersey
PI 666674	1758.001	PL		No. 41 cranberry	United States, Oregon
PI 554987	505.001	PL		Olson's Honkers	United States, Oregon
PI 657169	1680.002	PL		Olson's Honkers - Ray Gardner - Bandon	United States, Oregon
PI 555003	749.001	PL	TC	Paradise Meadow	United States, Massachusetts
PI 555005	751.001	PL	TC	Perry Red	United States, Massachusetts
PI 614077	1297.001	PL	TC	Pilgrim	United States, New Jersey
PI 657168	1679.002	PL	TC	Pilgrim - Floyd Brown - Bandon	United States, Oregon
PI 555004	750.001	PL	TC	Pride	United States, Massachusetts
PI 554993	666.001	PL	TC	Prolific	United States, Michigan
PI 618060	1047.001	PL		Rezin McFarlin	United States, Wisconsin
PI 618061	1048.001	PL		Rezin NatTCe	United States, Wisconsin

PI 555002	748.002	PL	TC	Round Howes	United States, Massachusetts
PI 555013	775.002	PL	TC	Searles	United States, Wisconsin
PI 555013	775.003	PL		Searles	United States, Wisconsin
PI 555014	776.001	PL	TC	Shaw's Success	United States, Massachusetts
PI 554972	110.001	PL	TC	Stankovich	United States, Oregon
PI 618059	1046.001	PL		Stanley	United States, Massachusetts
PI 614078	1298.001	PL	TC	Stevens	United States, Maryland
PI 657171	1682.002	PL		Stevens - Bob Donaldson - Floras Lake	United States, Oregon
PI 657162	1673.002	PL		Stevens - Manicke - Bandon	United States, Oregon
PI 657163	1674.002	PL		Stevens - Northside - Bandon	United States, Oregon
PI 657164	1675.002	PL		Stevens - Southside - Bandon	United States, Oregon
PI 657172	1683.002	PL		Stevens - Stu Peterson - George Bushman	United States, Oregon
PI 657161	1672.002	PL		Stevens - Yellow RTCer	United States, Oregon
PI 555006	752.001	PL	TC	Wales Henry	United States, Massachusetts
PI 555007	753.001	PL	TC	Whiting Randall	United States, Massachusetts
PI 614079	1299.001	PL	TC	Wilcox	United States, Maryland
PI 618064	1051.001	PL		WSU 108 cranberry	United States, Washington
PI 618063	1050.001	PL		WSU 77 cranberry	United States, Washington
PI 555028	832.001	PL	TC	Yellow Bell Open Pollinated	United States, Maine
PI 618025	929.001	PL	TC	V. macrocarpon Badger Pit CA	United States, California
PI 618171	1317.001	PL		V. macrocarpon Blue Hill 2	United States, Maine
PI 618028	933.001	PL		V. macrocarpon East pit CA	United States, California
PI 618026	931.001	PL		V. macrocarpon Lonesome Lake CA	United States, California

PI 554977	250.001	PL		V. macrocarpon Maine	United States, Maine
PI 555025	829.001	PL		V. macrocarpon Maine	United States, Maine
PI 555026	830.001	PL		V. macrocarpon Maine	United States, Maine
PI 555027	831.001	PL		V. macrocarpon Maine	United States, Maine
PI 555029	833.001	PL		V. macrocarpon Maine	United States, Maine
PI 555017	803.001	PL		V. macrocarpon Maine 70-28	Canada, Nova Scotia
PI 618009	896.001	PL		V. macrocarpon Maryland	United States, Maryland
PI 613184	913.001	PL		V. macrocarpon MD Allen 11	United States, Maryland
PI 613185	914.001	PL		V. macrocarpon MD Allen 12	United States, Maryland
PI 618018	916.001	PL		V. macrocarpon MD Allen 14	United States, Maryland
PI 638754	911.001	PL		V. macrocarpon MD Allen 9	United States, Maryland
PI 554989	660.001	PL		V. macrocarpon Minnesota	United States, Minnesota
PI 555020	823.001	PL		V. macrocarpon NH#2	United States, New Hampshire
PI 555021	824.001	PL		V. macrocarpon NH#3	United States, New Hampshire
PI 555022	825.001	PL		V. macrocarpon NH#3	United States, New Hampshire
PI 618231	1384.001	PL		V. macrocarpon Nova Scotia	Canada, Nova Scotia
PI 618231	1384.002	PL		V. macrocarpon Nova Scotia	Canada, Nova Scotia
PI 618086	1085.001	PL		V. macrocarpon NY	United States, New York
PI 618030	935.001	PL		V. macrocarpon Oregon	United States, Oregon
PI 554974	113.001	PL		V. macrocarpon Poole	United States, Oregon

PI 555031	876.001	PL		V. macrocarpon Tennessee	United States, Tennessee
PI 618014	906.001	PL		V. macrocarpon Tennessee Site TC	United States, Tennessee
PI 555015	777.001	PL		V. macrocarpon Thunder Lake 3	United States, Wisconsin
PI 555016	778.001	PL		V. macrocarpon Thunder Lake 4	United States, Wisconsin
PI 613183	905.001	PL		V. macrocarpon Virginia Site III	United States, Virginia
PI 555019	809.001	PL		V. macrocarpon VT 1	United States, Vermont
PI 618020	918.001	PL		V. macrocarpon WV Allen 16	United States, West Virginia
PI 618022	920.001	PL		V. macrocarpon WV Allen 18	United States, West Virginia
PI 618015	909.001	PL	TC	V. macrocarpon WV Allen 7	United States, West Virginia
PI 657241	1792.001	PL		V. marcocarpon H-PA-2007-04	United States, Pennsylvania

[z]Cultivars with the same name are being compared through molecular techniques to confirm identity. Duplicate accessions will be eliminated once determination is completed.

3.1.2 Genetic coverage and gaps

Clonal holdings

The collection presently has about 85 cultivars. A recent study was conducted using 12 simple sequence repeats (SSRs) to examine clonal purity and cultivar relatedness of 271 plants from 77 accessions representing 66 named cultivars in the NCGR collection (Schlautman et al. in preparation). Intra-cultivar variants (sub-clones) existed in the germplasm collection, a problem that likely stems from past misidentification or mixed clones of the accessions acquired by the NCGR. Consensus and true-to-type genotypes were found for many cultivars and wild selections by comparisons of genotypes in this study with previous ones, and a pedigree analysis. However, others were apparently absent suggesting that the collection can still be improved by sampling genotypes in cranberry bogs from commercial marshes across the growing regions or from breeders.

Fig. 3.1.2.1 Heritage cultivars to fill gaps in NCGR Collection

AJ	Bain McFarlin	Champion	Habelman2	Prolific
Bain 2	Bennett	Crowley	Hollison	Round Howes
Bain 4	Bugle: Wareham Type	Drever	No. 41	Searles
Bain 5	Centennial	FoxboroHowes	Perry Red	Stanley
Bain 9	Centerville	Gebhardt Beauty	Pride	

Domestic Collection Gaps.

Other heritage cultivars from the U.S. and wild accessions unrepresented geographically in the collection are being sought to broaden representation of cranberry diversity in the collection. Species representatives are especially needed from northeastern North America including the Eastern coast of the United States and Northeastern Canadian Maritime Provinces; from the Appalacian Mountains in the south; and from the northern Midwestern states, such as Minnesota, Michigan, and Wisconsin. Recent collections from USDA scientists in the mid-west will be donated to the NCGR *ex situ* collection.

During the past several decades, *in situ* conservation strategies have been established between the US Department of Agriculture and sister agencies, such as the U.S. Forest Service, as well as state heritage conservation programs in the Eastern U.S. American crop wild relatives of cranberry are prime candidates for *in situ/ex situ* conservation collaborations because of species distribution in many National Forests, state parks, and heritage sites from the Mid-western to the Eastern U.S.

List of designated 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.*
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.*
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.*

Crop: CRANBERRY

(compiled by Dr. Blanca León)

Crop taxon:

1. ***Vaccinium macrocarpon* Aiton – cranberry**

Crop wild relatives:

Primary

1. *Vaccinium macrocarpon* Aiton [wild types]

Secondary

1. *Vaccinium oxycoccos* L.

Crop: LINGONBERRY
(compiled by Dr. Blanca León)

Crop taxon:

1. ***Vaccinium vitis-idaea* L. – lingonberry**

Crop wild relatives:

Primary

1. *Vaccinium vitis-idaea* L. [wild types]

Secondary

1. *Vaccinium myrtillus* L.
2. *Vaccinium uliginosum* L.

3.1.3 Acquisitions

Plants

From any country plant material must be obtained from the USDA Animal and Plant Health Inspection Service. *Vaccinium* plants and plant parts from Canada are prohibited and a permit is required. Permits can be obtained through application the USDA APHIS PPQ website http://www.aphis.usda.gov/plant_health/permits/

APHIS works with state departments of agricultural, such as the Oregon Department of Agriculture (ODA) to provide inspection of plant material for the *Vaccinium* genebank in Corvallis.

Seeds

Fruit from foreign countries is prohibited. Seed must be extracted from the fruit prior to importation from foreign sources.

To extract seed, fruit are soaked in solution of 5% 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 can be placed in coin envelopes and placed in aluminized plastic envelopes and stored at -20^{o}C. Seeds are germinated and plant representatives are chosen from vigorous seedlings.

3.1.4 Maintenance

Clonal storage

The pathogen-tested primary *Vaccinium* collection is maintained under screen. Two containers are preserved for each genotype. The highbush cultivars are alternated with prostrate-growing accessions on benches in the screenhouse to maximize useage of space (Fig. 1).

We apply a pumice topdress (collar) to finished and intermediate sized plant material. The goal is to create a sterile (dry and inorganic) surface that will prevent weed and moss growth. This also can prevent or reduce fungus gnats.

We dibble, or bury our fertilizer under the topdress as part of this goal. This topdress combined with our stable, bark-free medium creates a growing system that greatly reduces water usage. This in turn reduces nutrient leaching, salt build-up, and moisture stress.

The abrupt change from fine growing medium to coarse pumice breaks the hydrolic conductivity between these materials and prevents capillary movement of water to the pot surface. Water in the medium is lost primarily through transpiration via stomata and not evaporation from the pot surface.

This topdress is a third component to the physical structure of our growing system. The other two are: Pot height (distance of crown to perched water table) and percent free air space. Tall pots with good aeration give healthy growth. The pumice collar reduces maintenance effort (sanitation and watering) and conserves resources (nutrients). The drawback of this system is that it can be difficult to evaluate moisture levels and develop a watering schedule. Scratching the surface to see moisture and pot weight are effective in gauging watering frequency. Overall, for us, the pumice topdress reduces significantly reduces cultural risk to containerized plant material.

The pumice collar is ideal for vigorous or pot bound material that needs frequent water. If you put a pumice collar on weak or poorly rooted material that needs a well aerated medium, you can get saturated conditions and loss of material. In this case, it is better to allow the plants to get established and apply the topdress later. I'm recommending a pumice collar for healthy, typical material. For xeric or high montane material that needs superior drainage, or has a prolonged dry dormancy, a pumice collar should only be used over medium with superior porosity and only after establishment or not at all. For slow growing montane material this is a compromise between control of fungus gnats and root aeration.

Seed storage

After collection and extraction, seeds are put into manila seed envelops and then into plastic-aluminum envelops for storage in -20^{o}C chest freezers in Corvallis. With quantities above 2,000, roughly half are shipped to USDA Ft. Collins, Colorado, and about one quarter are shipped to Svalbard Global Seed Vault in Norway for long term remote conservation.

3.1.5 Distributions and outreach

Cranberries are distributed as stem cuttings, tissue cultures, pollen, flowers, leaves, or seed. For most plant requests, cuttings are available for distribution during the dormant season from November through January. Cold stored tissue cultured plants in plastic packets (depending on availability) or seeds can be distributed any time of year.

3.2 Associated information

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

NCGR website: http://www.ars.usda.gov/main/site_main.htm?modecode=53-58-15-00

Passport information
Genotypic characterization data
Phenotypic evaluation data

Cranberry information is searchable on the new GRIN-Global database.
http://www.grin-global.org/index.php/Main_Page

3.3 Plant genetic resource research associated with the NPGS

Project sponsored by UDSA NIFA: Specialty Crop Research Initiative blueberry genomics

3.3.1 Future Goals and emphases

- Obtain wild cranberries with pest resistance
- Obtain primary, secondary, tertiary crop wild relatives with high fruit qualities
- Obtain heritage cultivars from state agricultural experiment stations or elsewhere in the US
- Obtain wild cranberry relatives from Asia to Northern America
- Analysis of fruit content variability within the genus

3.3.2 Significant accomplishments

- Significant plant collections from the US in multiple collecting trips over 30 years.
- Significant plant collections of blueberry crop wild relatives were obtained from Canada, Japan, China, Russia, and Vietnam (Hummer et al. 2016)
- Conservation of heritage cranberries dating back to the 1800s.
- Tissue culture core cultivars and species clones in the NCGR-Corvallis and at the NCGRP Ft. Collins.
- Wild cranberry populations in National Forests across the US are under evaluation for potential as in situ genetic reserves (USDA-ARS, USFS, Univ. of Wisconsin).

3.4 Curatorial, managerial and research capacities and tools

3.4.1 Staffing for *Vaccinium* management

0.1 FTE Cat. 4 support scientist Curator
0.1 FTE Cat. 4 plant pathologist/ testing and clean up
0.1 FTE Cat. 4 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/cryogenic 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- for plant management

1.3 FTE total USDA labor for cranberry efforts

3.4.2 Facilities and equipment	**ft^2**	**m^2**
1 Screenhouses for *Vaccinium* only	6,000	700
1 polycarbonate growing area	6,000	700
(below only 1/10 for blueberry)		
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 from OSU starting January 1, 1978)
(Lease has been signed for additional 25 year extension 2004 through 2029)
Planted (other non-strawberry 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, rtPCR)
Plant propagation equipment (mistbed, propagation houses, quarantine facility)
Field propagation

3.5 Fiscal and operational resources

Federal funding to support federal *Vaccinium* germplasm management at NCGR-Corvallis: FY 2016 – $153,000.

About $10,000 per annum to fund small fruit germplasm evaluation proposals from USDA Crop Germplasm Committee evaluation grants. In addition plant exploration/exchange funding can be applied for through the USDA annual granting process.

4. 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) (2 pp. maximum)

- *In situ* cranberry conservation effort between USDA ARS and Forest Service beginning 2013 for 5 years. Plans are to extend and expand this effort
- Verify each of the genotypes in the collection using molecular markers. (SSR, SNP, sequencing).
- Establish tissue culture collection of complete cultivar collection.
- Store seed samples of *Vaccinium* species both at NCGRP- Ft. Collins and at Svalbard Global Seed Vault.

5. Prospects and future developments

- Develop molecular markers, SNPs, or sequencing to distinguish cultivars at the subclonal level.
- Screen cranberry germplasm for resistance for the regionally important key insects.
- Screen cranberry germplasm for resistance for the regionally important key diseases.
- Improve efficiency of containerized collections of cranberry plants for long-term conservation.
- Regenerate seedlots of accessions that were wild collected for more availability to requestors.
- Continue and expand on-going *in situ* efforts for cranberry conservation.

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7. Appendices

Appendix Table 1. Cranberry crop wild relative species and synonyms listed in GRIN, October 2017.

1. ***Vaccinium erythrocarpum*** **Michx.**
2. ***Vaccinium erythrocarpum*** **subsp.** ***erythrocarpum***
3. ***Vaccinium erythrocarpum*** **subsp.** ***japonicum*** **(Miq.) Vander Kloet**
4. ***Vaccinium hybr.***
5. ***Vaccinium macrocarpon*** **Aiton**
6. ***Vaccinium oxycoccos*** **L.**
7. ***Vaccinium vitis-idaea*** **L.**
8. *Vaccinium vitis-idaea* subsp. *minus* (Lodd. et al.) Hulten (=***Vaccinium vitis-idaea*** **L.**)
9. *Vaccinium vitis-idaea* var. *minus* Lodd. et al. (=***Vaccinium vitis-idaea*** **L.**)

Appendix Table 2. Cranberry and crop wild relaties species held at the NCGR-Corvallis (Grin-Global October 2017)

Species name	No. accessions
Vaccinium erythrocarpum	5
Vaccinium erythrocarpum subsp. japonicum	3
Vaccinium hybr.	74
Vaccinium macrocarpon	113
Vaccinium oxycoccos	74
Vaccinium vitis-idaea	109

Appendix Table 3. Viruses that infect Cranberries

Virus name	Acronym	Genus	Transmission
Blueberry red ringspot virus	BRRV	*Soymovirus*	?
Blueberry scorch virus	BlScV	*Carlavirus*	aphids/non-persistent
Blueberry shock virus	BlShV	*Ilarvirus*	pollen/seed ◊
Tobacco streak virus	TSV	*Ilarvirus*	pollen/seed □◊

◊ Also transmitted by pollen feeding arthropods
□ Pollen and seed transmitted

Appendix Table 4. Regional occurrence of viruses in cranberry

Virus name	Regional occurrence					
	North America	South America	Europe	Africa	Asia	Australia New Zealand
Blueberry red ringspot virus	Yes	N/A	Yes	N/A	Yes	Yes
Blueberry scorch virus	Yes	N/A	Yes	N/A	N/A	N/A
Blueberry shock virus	Yes	N/A	Yes?	N/A	N/A	N/A
Tobacco streak virus	Yes	Yes	Yes	Yes	Yes	Yes

Appendix Table 5. Virus detection methods and frequently used primer sequences.

Virus	Detection methods	Primer sequences
Blueberry red ringspot virus	ELISA/PCR	(RRSV3) ATCAGTCCCAGAAGAAAAGAAGTA
		(RRSV4) TCCGAAAAATAGATAGTGTCAGC 549bp
Blueberry scorch virus	ELISA, RT-PCR	(F) GAAAGAAGCACCGGCTCAATC
		(R) GGAGATCTTGGCCATTTGCTC 380bp
Blueberry shock virus	ELISA; RT- PCR degenerate ilar primers	(Ilar1F5) GCNGGWTGYGGDAARWCNAC
		(Ilar2R9) GGTTGRTTRTGHGGRAAYTT ~ 380bp
Tobacco streak virus	ELISA, RT-PCR	(TSV CP F) ACGAGTATTAAGTGGATGAATTCT
		(TSV CP R) ACTTACAATACGTCGAGGTGTG 872bp