USDA *Fragaria* Crop Vulnerability Statement 2017

Summary

In 2014, about 8.1 million tonnes of strawberries, *Fragaria* L., were produced worldwide (FAOSTAT 2017). Strawberries are an economically important crop in the US. At 2.8 billion dollars, the US 2014 strawberry crop was valued second only to grapes among noncitrus fruits (USDA-NASS 2015). After China, the US is the second largest producer with approximately 17% of the world's crop. California leads the nation in strawberry production with 91% of US strawberries produced on 68% of US strawberry production area, followed by Florida, the leading producer from December through February, with 7% of the crop from 18% of the US strawberry fields (USDA-NASS 2015). However, strawberries are grown widely throughout the US for a couple of reasons. They are highly perishable (Mitcham 2002) so that locally-grown strawberries are particularly valued by some consumers. They also are a valuable crop for growers at a national average of $46,737 gross per acre, ranging from $7,200 per acre in Pennsylvania to $59,850 in California (USDA-NASS 2015). The high value of strawberries is due in part because of their popularity. Strawberries rank as the fifth most popular fresh-market fruit in the United States (USDA-ERS 2012), with annual per capita consumption increasing steadily to 3.62 kg from 2002 to 2013 (USDA-ERS 2016).

Strawberry species have a complex background including natural diploid, tetraploid, pentaploid, hexaploid, octoploid, enneaploid, and decaploid genomes. Centers for strawberry species diversity include Eurasia and North and South America. The primary cultivated gene pool is octoploid, and the hybrid berry that dominates the commercial market has only been developed within the last 260 years. Wild species distributions are limited, and landraces may be lost with encroachment of human development. Molecular geneticists have realized the advantage of working with *Fragaria* and its small-sized genome. Breeders are incorporating new sources of wild plant material to reconstruct the original hybrid cross and to expand the restricted cultivated gene pool.

Internationally, 27 countries and two genebank networks maintain more than 12,000 accessions in about 57 locations. Roughly half of these accessions represent advanced breeding selections of the cultivated hybrid strawberry, *F. ×ananassa*, some of which are proprietary. It's estimated that, in addition to public collections, global private corporations also maintain a similar amount of proprietary cultivated hybrids for internal use.

The US national strawberry genebank is located at the US Department of Agriculture, Agricultural Research Service, National Clonal Germplasm Repository at Corvallis, Oregon. The NCGR genebank collection includes 42 *Fragaria* taxa and about 1800 accessions. The NCGR genebank includes a primary collection of living strawberry plants, protected in containers in greenhouses and screenhouses. Aphids, which vector viruses, are excluded from these houses. Integrated pest management techniques minimize powdery mildew, spider mites and other key pests. A core collection representing world species and heritage cultivars has been defined. A "supercore" collection of wild American octoploids has also been defined. A secondary backup core collection is maintained *in vitro* under refrigerated temperatures. A long-term backup core collection of meristems has been placed in cryogenic storage on site, and at the remote base location, National Center for Genetic Resource Preservation, Ft. Collins, Colorado.

At Corvallis, species diversity is represented by seed lots stored in -18 C or backed up in cryogenics. Seed accessions are not tested for viability nor are they regenerated due to insufficient funding. In addition, living plant representatives of major taxa are maintained in pots in screenhouses. Plants are tested for common viruses, viroids, and phytoplasmas as funding

allows. Plant identity is checked by comparison with written description, review by botanical and horticultural taxonomic experts, and evaluation by molecular markers, such as simple sequence repeat markers. SNP markers and genotyping by sequencing (GBS) approaches are under development.

The collection has been documented for accession, inventory, voucher images and morphological and genetic observations on the Germplasm Resources Information Network (GRIN) in Beltsville, Maryland. More than 5,600 strawberry accessions have been distributed to international and domestic requestors during the past 5 years.

The collection presently has about 440 cultivars. Other major cultivars from the US or Europe not in the collection are being sought to broaden representation of historical cultivars. Species representatives are especially needed from Alaska, Hawaii, Western and Southwestern United States (including Oregon, Montana, Utah, Arizona, New Mexico), across Canada, from Chile, Ecuador, Peru, China, Korea, India, Bhutan, Russia (Kurile Islands, Kamchatka, Amur) Japan, India, and Nepal.

1. Introduction to the crop

1.1 Biological features and ecogeographical distribution

The strawberry plant is a small herbaceous perennial with a fibrous root system, trifoliolate leaves, branch crowns, stolons, and branched inflorescences all emanating from a central crown at ground level. Although the above-ground portion of the commercially grown plant is around 30% to 35% fruit by dry weight (Fernandez et al., 2001), the fruit are over 90% water, accounting for a much greater proportion in fresh weight. A single plant can produce as much as 2.5 kg of fruit in a few weeks, though 0.5 kg per plant is more common. The plant propagates vegetatively by branch crowns and stolons, commonly called “runners.” Plants propagated this way by nurseries, breeders, and genebanks, are identical to their “mother plants.” The plant also produces seeds but nearly all the commercially propagated strawberries and many species are highly heterozygous, so the progeny from seed are not genetically identical to the parent. The requirement to propagate vegetatively creates significant challenges and requires greater expense than would be needed if individual genotypes could be maintained and propagated by seed.

The native distribution for crop wild relatives of *Fragaria* L. is circumpolar boreal, through Europe, East and Southeast Asia, North America (including Mexico), and, in addition, on a few Pacific Islands and into parts of South America (Darrow, 1966, Staudt, 1999; Staudt, 2009; Hummer et al., 2011).

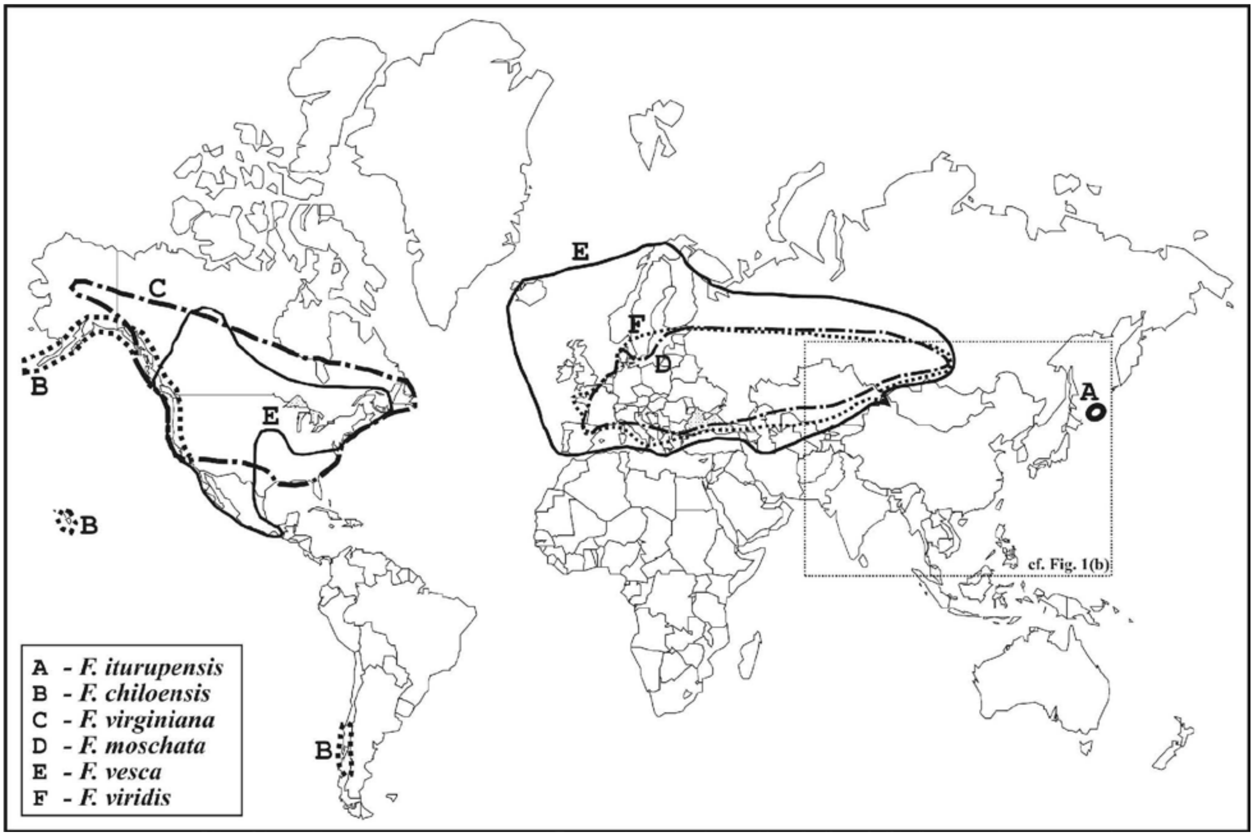


Fig. 1a. Geographic distribution of *Fragaria* species: octoploid species, hexaploid species (*F. moschata* and *F. vesca* and *F. viridis*. Staudt, G. 2009. Strawberry Biogeography, Genetics, and Systematics. Acta Hort. 842:71-84.

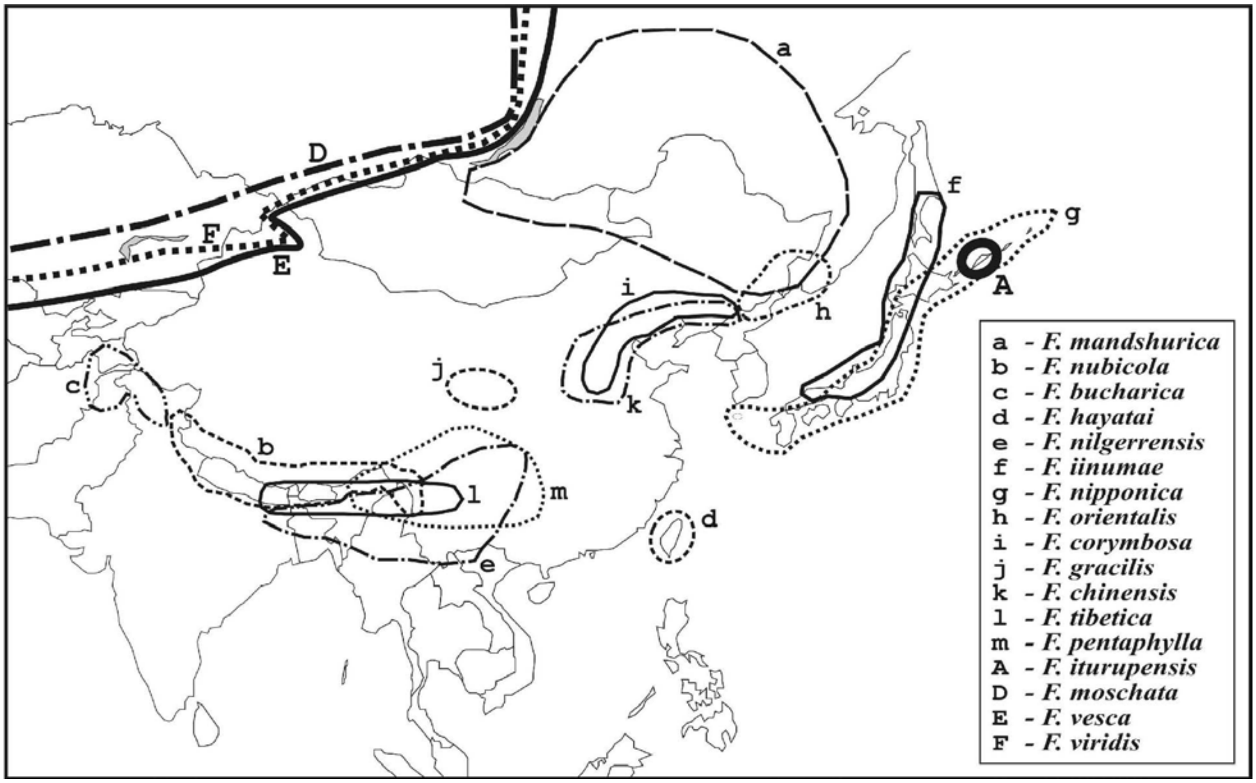


Fig. 1b. Asian *Fragaria* species. Staudt, G. 2009. Strawberry Biogeography, Genetics, and Systematics. Acta Hort. 842:71-84.

The majority of the 20+ wild strawberry species occur in Asia, although the two wild octoploid progenitors of the hybrid cultivated strawberry, *F.* ×*ananassa* subsp. *ananassa* are American. A white-fruited beach strawberry (*F. chiloensis* subsp. *chiloensis* forma *chiloensis* from Chile was the mother, and the Virginian (*F. virginiana* subsp. *virginiana*) from eastern North America with small red fruit supplied the pollen. These American species were brought to the Jardins du Château de Versailles (France), early in the 18th century, where the accidental cross that produced the original hybrid strawberry occurred. The large hybrid was first described by Antoine Duchesne. While the cultivated strawberry is recognized as a significant economically important fruit, conservation support for wild relatives lags behind those of other economically and agriculturally important crops.

Fragaria species exist as a natural polyploid series (Appendix Table 1) from diploid through decaploid. Diploid *Fragaria* species are endemic to Eurasia and North America. *Fragaria vesca* subsp. *vesca* is native from the west of the Urals throughout northern Europe, and across the North American continent. However, this diploid species is highly specialized. It is not native to the Kurile, Aleutian, or Hawaiian Archipelagos according to flora of those regions (Hultén 1968). It has been introduced in many of those areas.

Diploid strawberry species are reported on many of the islands of and surrounding Japan, in Hokkaido, on Sakhalin, and in the greater and lesser Kurile Islands (Makino 1940). Diploid and tetraploid species are native to Asia, particularly in China, but also in Siberia and the

Russian Far East. Wild, naturally occurring pentaploids ($2n = 5x = 35$) have been observed in California (*F. ×bringhurstii*) and China (Lei et al. 2005). These strawberries exist in colonies with other ploidy levels nearby. The only known wild hexaploid ($2n = 6x = 42$) species, *F. moschata*, is native to Europe as far east as Lake Baikal. This species is commonly known as the musk strawberry (Hancock, 1999).

Wild octoploid species are distributed from Unalaska eastward in the Aleutian Islands (Hultén 1968), completely across the North American continent, on the Hawaiian Islands, and in South America (Chile) (Staudt 1999). Wild decaploids ($2n = 10x = 70$) are native to the Kurile Islands (*F. iturupensis*) (Hummer et al., 2009) and the old Cascades in western North America (Hummer, 2012). A description of each *Fragaria* species can be found in Hummer et al. (2011).

1.2 Genetic base of crop production

Currently, the strawberry of greatest commercial value, *F. ×ananassa*, is an interspecific hybrid between two octoploid species *F. chiloensis* and *F. virginiana*. Because the commercial strawberry also is octoploid, the progenitors and other octoploid species are most likely to be of value in introgressing valuable genes such as those for resistance to new pests.

E.L. Sturtevant, through U. P. Hedrick (1919) and Darrow (1966) describe early references for European strawberry from the Ancient Roman verses of Virgil and Ovid, and the glancing mention in Pliny's *Natural History*. Darrow (1966) pointed out that this fruit was not a "staple of agriculture" to explain its exclusion from Theophrastus, Hippocrates, Dioscorides or Galen.

By the 1300s, the French began transplanting *F. vesca*, the wood strawberry, from the wilderness into the garden. In 1368, King Charles V had his gardener, Jean Dudoy, plant no less than 1,200 strawberries in the royal gardens of the Louvre, in Paris (Darrow, 1966). Written references to the strawberry in Shakespeare and his contemporaries may indicate the success of the plant in the gardens of that time. In 1530, King Henry VIII paid ten shillings for a "pottle of strawberries" (slightly less than 250g) according to his Privy Purse Expenses (Darrow, 1966).

In addition to the alpine strawberry, Darrow (1966) noted *F. moschata* was cultivated in Europe. Karp (2006) described this species as the most aromatic strawberry. *Fragaria viridis* the "green" strawberry was also gathered and eaten. *Fragaria ×ananassa*, the "pineapple strawberry" was the species name given to the accidental hybrid of *F. chiloensis* subsp. *chiloensis* f. *chiloensis* and *F. virginiana* subsp. *virginiana* in Europe by Duchesne in the early 18th century (Hancock 1999).

Between the 10^{th} and the 18^{th} centuries, in Japan, the ancient word "ichibigo" referred to many berry crops (including Japanese strawberry species and the low-growing *Rubus pseudo-japonica*), gathered from the wild (Oda and Nishimura, 2007). The word migrated to "ichigo," now the term of reference for the modern day *Fragaria* species. The cultivated *F. ×ananassa* was first brought into Japan from the Netherlands in early to mid-19^{th} Century.

The Virginia strawberries impacted the European strawberry industry of the 1800s with their high yields and deep red color resulting in the name "scarlet strawberry." The scarlet strawberry was cultivated in Europe and some important cultivars included: 'Oblong Scarlet,' 'Grove End Scarlet,' 'Duke of Kent's Scarlet' and 'Knight's Large Scarlet.'

At the time of the re-introduction of the scarlet strawberry to the United States in the early 1700s, *F. virginiana* plantings were established in Boston, New York, Philadelphia, and Baltimore. 'Hudson' a vigorous, soft fruited and high flavored *F. virginiana* clone was considered the first most important American strawberry (Hancock, 1999). The attractive color, large size and acceptable flavor made it favorable for making jam. It was used through the early part of the 20th century (Fletcher 1917). Desirable horticultural traits, such as winter hardiness, frost tolerance, resistance to red stele, adaptation to diverse environmental conditions, and inter-fertility with the cultivated strawberry (Hancock et al. 2002), made *F. virginiana* a valuable genetic resource for breeders. A *Fragaria virginiana* subsp. *glauca* clone from Hecker Pass (Utah, US) was the primary source of the day-neutral trait in the cultivar development program of the University of California in the 1970s and 1980s.

Importation of Chilean clones to Europe in the early 18th century resulted in the accidental hybridization with *F. virginiana* subsp. *virginiana* from North America forming the now cultivated *F. ×ananassa* subsp. *ananassa*, now known as the hybrid of commerce. *Fragaria chiloensis* has been used in breeding programs as a source of winter hardiness (Staudt 1999), resistance to strawberry root diseases and virus tolerance (Lawrence et al., 1990).

Since the mid-1800s, breeding in Europe and United States has resulted in hundreds of cultivars from 35 breeding programs (Faedi et al. 2002). The *F. ×ananassa* subsp. *ananassa* includes these cultivated species originating from the accidental hybrids first recognized in France around 1750. Breeding work in Alaska utilized *F. chiloensis* to develop Sitka hybrids that were winter hardy and suited for climatic conditions in Alaska (Staudt 1999b).

In North America, natural hybridization between *F. ×ananassa* subsp. *ananassa,* that escape cultivation, with subspecies of *F. chiloensis* and *F. virginiana* have been observed. These hybrids are usually identified in the wild by the large berries, sometimes erratic fruit set, and fruit taste. *Fragaria chiloensis* populations resulting from introgression into the hybrid octoploid were observed in California (*F. chiloensis* subsp. *lucida*) and Chile (*F. chiloensis* subsp. *chiloensis* f. *patagonica*). Introgression of the cultivated strawberry into wild populations of *F. virginiana* subsp. *grayana* occurs in the Southeastern United States.

Tribal Use of Primitive Forms

In South America, the Mapuche (Mäpfuchieu) and Huilliche Indians, the indigenous people of central and southern Chile, cultivated strawberries. Their economy was based on agriculture until the appearance of the Spanish conquistadores. They developed a landrace of the white Chilean strawberry (*F. chiloensis* subsp. *chiloensis* f. *chiloensis*.) and cultivated this fruit, undisturbed for thousands of years until 1550-1551. The Spanish considered this fruit as a spoil of conquest. Pedro de Valdivia and his men brought this fruit to Cuzco, Peru in 1557, where it was described as the 'chili' (Darrow 1966). Spread of the Chilean berries to other countries within South America followed the Spanish invasion (Hancock 1999). Strawberry acreage found in Ecuador was reported to be largest observed in South America during the period between 1700 and 1970 (Finn et al. 1998). Despite the higher yields obtained with *F. ×ananassa* in Chile (20-70 t/ha), its flavor and aroma has been described as lower than that of *F. chiloensis* (Retamales et al. 2005). High yielding *F. ×ananassa* cultivars displaced the local Chilean landrace cultivars in the 20th century (Retamales et al. 2005).

1.3 Plant Breeding and its products

Public strawberry breeding efforts in the US are almost exclusively designed to release cultivars of quality ready for growers to use in production. Very little enhanced germplasm has ever been released. Most programs are working towards development of both once-fruiting and repeat-fruiting cultivars, though one is usually stronger than the other. Most cultivars are released under plant patents. The transition from the breeding program to the grower passes through nurseries. Nurseries propagate new cultivars per licensing agreements with the breeder's institution. Great variation exists in the specifics of the process.

California leads the nation in strawberry production and is well-supported by multiple public and/or private breeding programs and related research efforts. The public strawberry breeding program was initiated in the 1930s through the University of California (Hancock, 2006). Dr. Steve Knapp, the current lead strawberry breeder for the state assumed leadership of the program in 2015. As with many plant breeding programs the transition between breeders includes changes in direction and logistics that can result in a brief lag between the last cultivar from the previous leadership and the first cultivar from the new leadership. Advanced selection testing is expected in 2018. The University of California Foundation Plant Services maintains a collection of current UC strawberry cultivars, annually tests them for viruses and genetic identity, and distributes them to nurseries as either whole plants or in tissue culture from meristems.

The leading private strawberry breeding program in California and the world is Driscoll's Incorporated program, headquartered in Watsonville CA (Sjulin, 2006). The history of this company recently was published in The New Yorker (https://www.newyorker.com/magazine/2017/08/21/how-driscolls-reinvented-the-strawberry). This private-sector program is well-supported by its in-house research in plant genetics, pathology, entomology, production, and marketing. Dr. Phil Stewart is the current director of strawberry breeding. He leads other Driscoll's breeders in the state of Florida as well as in Mexico and several other countries. Driscoll's cultivars are protected under plant patent but are not released to nurseries. Plants are produced and shipped to Driscoll's growers. This arrangement is key to protecting Driscoll's intellectual property.

Berry Genetics Inc. (Freedom, CA), Lassen Canyon Nursery (Redding, CA), and the newly formed California Berry Cultivars (Watsonville, CA), and Sweet Darling Sales, Inc. (Aptos, CA) are other successful private companies operating in California. Driscoll's Incorporated and Berry Genetics have private breeding programs in Florida in addition to California.

Florida is the largest winter strawberry producer in the US and the second largest strawberry-producing state. The public strawberry breeding program in Florida was begun in the 1940s and currently is led by Dr. Vance Whitaker, University of Florida. This program is extremely well supported by collaborative research work on horticulture, pathology, virology, entomology, nematology, genetics, and consumer science. New cultivars are protected with plant patents and released to nurseries through licensing agreements. The Florida production system requires fall planting. Florida cultivars are primarily short-day varieties with some day-neutral focus in recent years. These varieties have little to no chilling or vernalization requirement. After heat treatment, meristems from runners are excised, grown in sterile culture and tested for known viruses via ELISA and PCR, in-house. Tissue cultures are released to licensed foundation nurseries for propagation at least two years prior to commercialization/release of a new cultivar. Canadian and Appalachian nurseries are the primary sources of plants for Florida growers, due to the early fall planting practice.

On the east coast, after Florida, the two states with greatest production, New York and North Carolina, also have their own public strawberry breeding programs. These programs, led by Dr. Courtney Weber at Cornell University and by Dr. Gina Fernandez at North Carolina State

University (NCSU), are not nearly as well supported as the programs in California and Florida. Both breeders also have responsibilities for raspberry and blackberry breeding programs. Researchers in related fields that could support the programs are free to pursue other research interests rather than being dedicated to the fruit breeding programs. New cultivars are released under plant patents. Production of virus-indexed plants to distribute to licensing nurseries has been a challenge for these and other less-supported programs. However, with the recent funding to the National Clean Plant Network (http://nationalcleanplantnetwork.org/Berry_CPN/), through the 2010 Farm Bill, it is possible for all strawberry breeding programs to have a common route to virus-index and propagate new cultivars to distribute to nurseries.

The Cornell University strawberry breeding program, begun in 1882, develops cultivars for the Northeast and regions with similar climates. Cornell cultivars often perform well in the Midwest, Mid-Atlantic, and New England states as well as eastern Canadian production areas. Though the program has been primarily focused on developing once-fruiting June-bearing cultivars for the tradional matted-row production system, the program has dedicated a small effort, since the mid-2000's, to developing repeat-fruiting cultivars for low-tunnels that produce strawberries in New York for about five months, spring to fall. Meristem explants are used by the breeder to produce virus-tested mother plants via tissue culture to send to licensed nurseries for propagation.

The NCSU breeding program develops cultivars for the southern region of the US (excluding FL) for both pick-your-own and commercial/shipping farms. To be successful in this region, cultivars need to have a low to moderate chilling requirement and a fruiting period that occurs primarily in a two month window in spring. Ideal plants would have high yields, firm fruit with excellent fruit flavor, resistance to insect and disease pressure, including but not limited to *Colletotrichum acutatum* and *C. gloeosporioides*. Production of virus-indexed plants to distribute to licensing nurseries is managed through the National Clean Plant Network center for strawberries, located on the NCSU campus.

Also serving Eastern growers, the USDA-Agriculture Research Service (USDA-ARS) has a breeding program lead by Dr. Kim Lewers at Beltsville, Maryland. Begun in 1910, the program's cultivars have performed well in the Mid-Atlantic, Northeast, Midwest, and regions with similar climates. Past once-fruiting cultivars were developed using matted row production systems, then annual plasticulture. Beginning in 2011, repeat-fruiting selections were tested in low tunnels fruiting nine months of the year (Lewers et al 2017). Many years of close collaboration with a series of plant pathologists have made the breeding population resistant to many diseases. Disease resistance remains a major emphasis, though now without a pathologist. Selections are tested for multiple viruses using rt-PCR. Infected selections are propagated through meristem culture and kept in a screenhouse to prevent re-infection. The selections are tested again in replicated field trials, because meristem culture changes strawberry phenotype (Hughes et al 2013). New cultivars were previously released without patent, but future cultivars will be protected with plant patents to maintain the original phenotype. The method for producing sufficient plants for distribution to licensing nurseries is problematic and evolving.

The USDA-ARS has a separate strawberry breeding program for the Northwest US at Corvallis, Oregon. This program is led by Dr. Chad Finn. Dr. Finn has additional responsibilities in breeding other berry crops. Collaborative researchers in supporting fields are not required to support the fruit breeding efforts. The Pacific Northwest requires strawberries that are suited to processing in addition to fresh market. To remain competitive, picking costs must be as low as possible, so the cultivars need to have large fruit borne on open plants so the fruit are visible and that pick easily with the calyces remaining on the plant when the fruit are picked. In addition, the fruit must have intense flavor, high sugars and acids, have excellent internal and external color and hold up well in the freezing and thawing process. Cultivars are protected by plant patents and licensed to nurseries.

The Washington State University strawberry breeding program, located at Puyallup began with the crosses made in 1941 by Dr. C.D. Schwartze. The program has been led since 1987 by Dr. Patrick Moore. Since the initiation of the program there have been 14 strawberry cultivars released, primarily for use in the Pacific Northwest. Eleven cultivars have been once-fruiting cultivars for processing or fresh, and three cultivars were repeat fruiting for fresh. In 2011 the repeat-fruiting program lead by Wendy Hoashi-Erhardt was re-initiated. Repeat-fruiting selections have been developed that are promising and are under evaluation. Cultivars are protected by plant patents and licensed by nurseries.

Canada's Agriculture and Agri-Food Canada supports a strawberry breeding program at Kentville, Nova Scotia. This Canadian breeding program, currently led by Dr. Beatrice Amyotte, has long-supplied cultivars for Northeastern and Midwestern US states. This breeding program is yet another that is not supported by researchers who are directed to support it. Previously, only once-fruiting cultivars have been released and most new cultivars have been released to nurseries without plant patent protection. The new focus of this program is on germplasm development as opposed to cultivar breeding, since the Canadian government anticipates that members of the strawberry nursery and production industries will take over the testing of improved selections and the release of commercial cultivars.

Since the 1950s, Agriculture and Agri-Food Canada has also had a strawberry breeding program in British Columbia. This program has worked closely with the USDA-ARS breeding program in Oregon, as well as the Washington State University breeding program and has released 10 cultivars adapted to the Pacific Northwest since its inception. In 2013, Agriculture and Agri-Food Canada divested the program as part of their shift from cultivar development efforts at stations across the country to focusing on germplasm development based at a single location. In 2013, the British Columbia Strawberry Growers' Association hired Dr. Michael Dossett to continue operation of the program on a reduced scale with soft funding. At the same time, the primary focus of the strawberry program shifted from the development of once-fruiting cultivars for the processing industry to repeat-fruiting cultivars for the fresh market. Cultivars released by the program are protected by plant patents and licensed by nurseries. Because of unstable funding, this program is not well supported, and the breeder has primary responsibilities in raspberries and blueberries.

1.4 Domestic and international crop production

1.4.1 U.S. (regional geography)

Strawberries are an economically important crop in the US. At 2.8 billion dollars, the US 2014 strawberry crop was valued second only to grapes among noncitrus fruits (USDA-NASS 2015). California leads the nation in strawberry production with 91% of US strawberries produced on 68% of US strawberry production area, followed by Florida, the leading producer from December through February, with 7% of the crop from 18% of the US strawberry fields (USDA-NASS 2015). However, strawberries are grown widely throughout the US for a couple of reasons. They are highly perishable (Mitcham 2002) so that locally-grown strawberries are particularly valued by some consumers. They also are a valuable crop for growers at a national average of $46,737 gross per acre, ranging from $7,200 per acre in Pennsylvania to $59,850 in

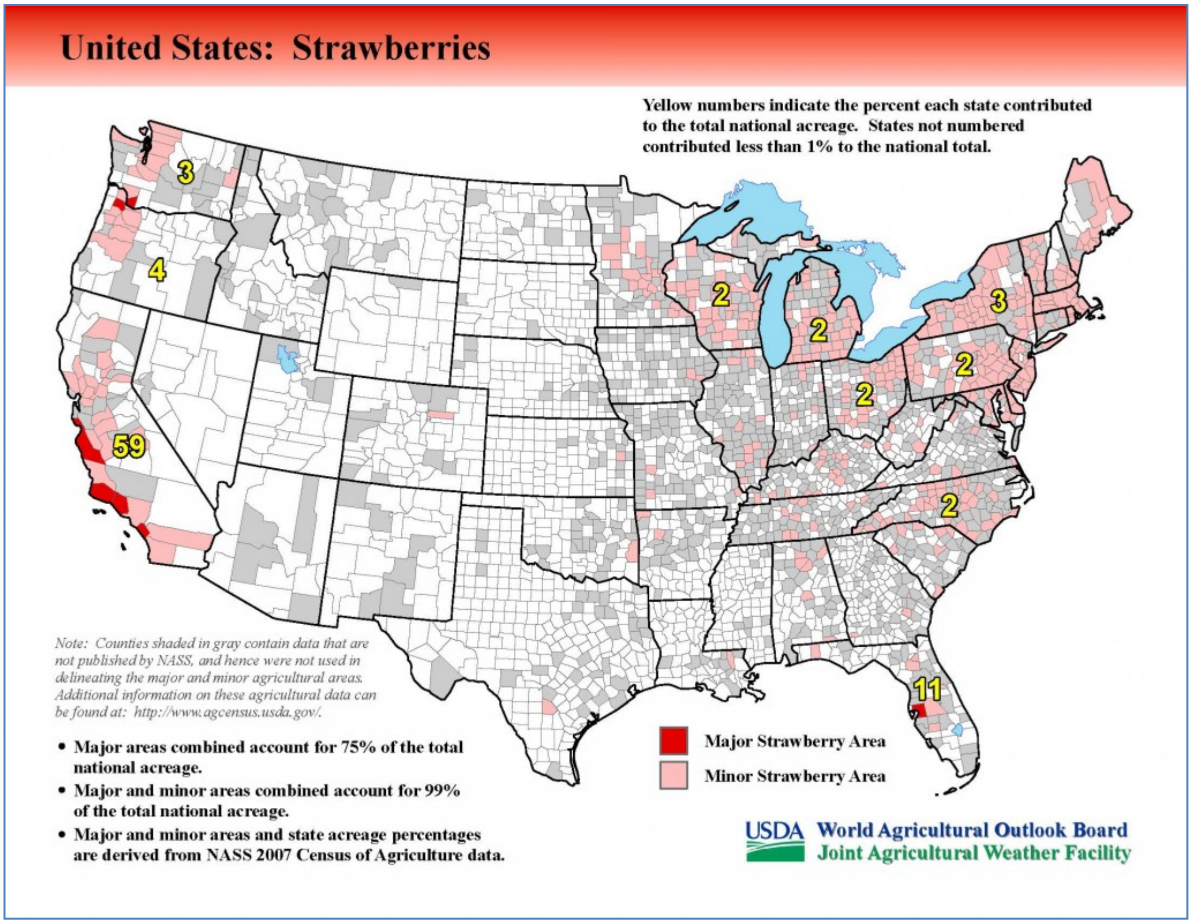
California (USDA-NASS 2015). The high value of strawberries is due in part because of their popularity. Strawberries rank as the fifth most popular fresh-market fruit in the United States (USDA-ERS 2012), with annual per capita consumption increasing steadily to 3.62 kg from 2002 to 2013 (USDA-ERS 2016).

Value of US Strawberry Production ($US Million)

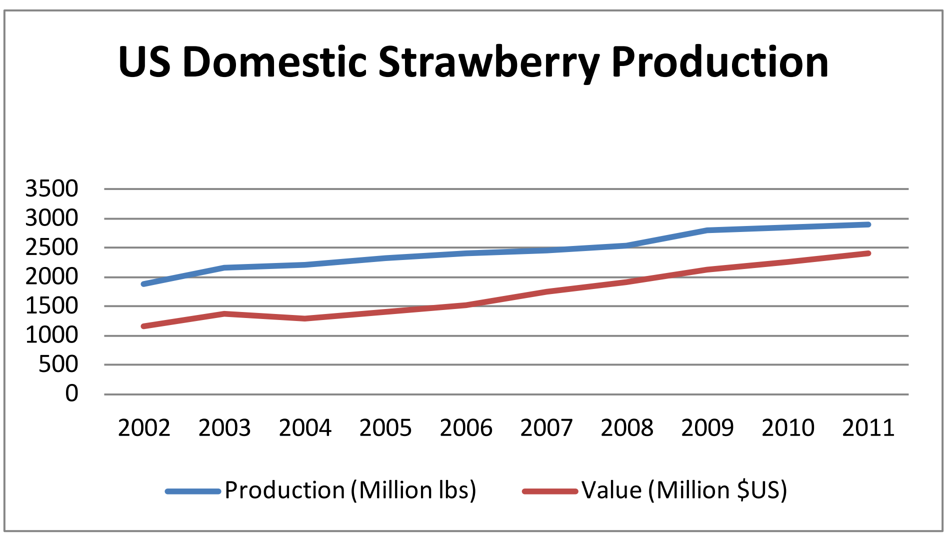
Year	Fresh	Processed	Total
2000	931.5	114.5	1,046.0
2001	955.9	114.2	1,070.1
2002	1,003.1	158.5	1,161.6
2003	1,230.6	144.6	1,375.1
2004	1,159.1	136.4	1,295.5
2005	1,248.4	148.0	1,396.4
2006	1,379.7	139.8	1,519.5
2007	1,620.2	130.9	1,751.1
2008	1,759.6	158.7	1,918.3
2009	1,970.9	158.7	2,129.6
2010	2,107.1	155.2	2,262.4
2011	2,204.2	195.2	2,399.4

Preliminary. Source: USDA, National Agricultural Statistics Service, *Noncitrus Fruits and Nuts*. 2013**.**

US Farm Gate: Grower receipt/lb		
Year	Fresh	Processed
2000	64.9	24.5
2001	75.8	29.2
2002	71.3	33.1
2003	74.9	28.1
2004	68.4	26.3
2005	68.9	28.9
2006	72.2	28.4
2007	82.1	27.7
2008	84.1	36.0
2009	86.1	30.9
2010	90.8	29.2
2011	94.4	34.8



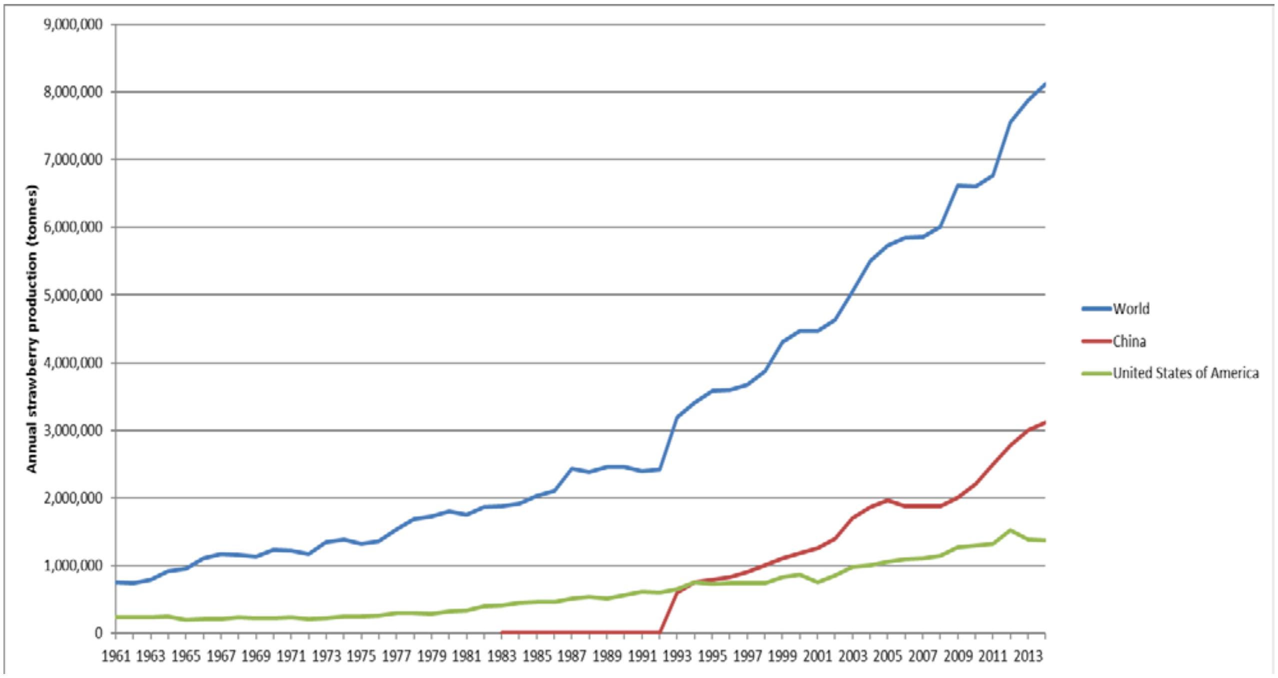
California dominates the US strawberry industry with over 80% of the total production.



Preliminary. Source: USDA, National Agricultural Statistics Service, *Noncitrus Fruits and Nuts. 2013*

1.4.2 International

In 2014, about 8.1 million tonnes of strawberries, *Fragaria* L., were produced worldwide (FAOSTAT 2017). After China, the US is the second largest producer with approximately 17% of the world's crop.



http://www.fao.org/faostat/en/#data/QC accessed 19 October 2017

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

In 2008, *Fragaria* genebanks were located in 27 countries, and, together with two genebank networks, maintained more than 12,000 strawberry accessions in about 57 locations (Hummer 2008). Roughly half of these accessions represented advanced breeding lines of the cultivated hybrid strawberry. A survey of the private sector indicated that, in addition to the public collections, global private corporations maintained another 12,000 proprietary cultivated hybrids for internal use. Unlike the public collections, however, these private collections were transitory in nature with proprietary genotypes being destroyed after intellectual property rights expire.

Primary collections at national genebanks consisted of living plants, protected in containers greenhouses or screenhouses, or growing in the field. Any plant material grown outdoors cannot be certified as pathogen negative. Secondary backup collections were maintained in vitro under refrigerated temperatures. Long-term backup collections of meristems were placed in cryogenic storage at remote locations to provide decades of security. Species diversity was represented by seed lots stored in -18°C or backed-up in cryogenics. Conservation of clonally propagated material, where genotypes were maintained, was 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.

Strawberries are a specialty crop. Limited world resources are available from each government for conservation of cultivated strawberries and their wild relatives. These limited resources constrain the management of strawberry resources in each country (Hummer, 2008). Many genebanks are unable to perform pathogen test protocols and maintain pathogen-negative plants that satisfy quarantine requirements. Training on standard protocols for germplasm maintenance is needed for staff of genebanks in developing countries. Coordination of inventory and characterization data between genebanks is also insufficient (Hummer, 2009).

In situ preservation of wild strawberries has been limited. The wild species in many regions of the world would be appropriate for such conservation efforts.

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

The commercial strawberry is an outcrossing crop that is sensitive to inbreeding (Morrow and Darrow, 1952; Melville et al., 1980). It is asexually propagated by runners, so most breeding programs select elite parents for intercrossing each generation. The strawberry germplasm base is broad, compared with that of other crops (Sjulin and Dale, 1987), as 53 founding clones made up the genetic base of 134 North American cultivars released since 1960. The octoploid genome is still so highly duplicated that it is easy to identify homeologous groups (Spigler et al, 2010). It's possible this level of duplication is one genetic factor responsible for the variability and genetic gain seen in closed breeding populations. If adequate population sizes are maintained and adequate selection pressure applied, changes in levels of homozygosity across generations appear to be minimal (Shaw, 1995). Since highly heterozygous genotypes can be propagated as runners, few breeding programs have developed hybrid cultivars using inbred lines, although a few cultivars have been developed in this manner.

Selfing has been used in a number of instances to concentrate genes of interest (Hancock et al., 1996) and to develop F-1 hybrid, seed-propagated commercial varieties (Bentvelsen et al, 1997), and backcrossing can incorporate specific traits. Barritt and Shanks (1980) moved resistance to the strawberry aphid from native *F. chiloensis* to *F. ×ananassa*. Bringhurst and Voth (1978, 1984) transferred the day neutrality trait from native *F. virginiana* subsp. *glauca* to *F. ×ananassa*. About three generations were necessary to restore fruit size and yield to commercial levels.

In 1817, formal strawberry breeding was initiated in England by Thomas A. Knight (Darrow 1966; Wilhelm and Sagen 1974). He was one of the first systematic crop breeders. He used clones of both *F. virginiana* and *F. chiloensis* in his crosses. He produced 'Downton' and 'Elton' cultivars, noted for their large fruit, vigor and hardiness. Michael Keen, a market gardener near London, also became interested in strawberry improvement about this time and developed 'Keen's Imperial' whose offspring, 'Keen's Seedling' is in the background of many modern cultivars. This cultivar dominated strawberry acreage for about 100 years. Thomas Laxton of England was the most active breeder during the latter part of the 18th century. He released 'Noble' and 'Royal Sovereign'. These two cultivars were grown on both sides of the Atlantic, and were popular until the middle of the 20th century. 'Noble' was known for earliness, cold hardiness and disease resistance. 'Royal Sovereign' was popular because of earliness, productivity, flavor, attractiveness and hardiness.

In 1836, Charles Hovey, of Cambridge, Massachusetts, produced the first important North American strawberry, 'Hovey', by crossing the European pine strawberry, 'Mulberry' with a native clone of *F. virginiana*. This was the first American fruit cultivar produced from an artificial cross. For a while this strawberry was the major pomological product in the country (Hedrick 1925). Albert Etter of California developed dozens of cultivars around the turn of the century with native *F. chiloensis* clones (Fishman 1987). His most successful cultivar was

Ettersburg 80 (1910), which was widely grown in California, Europe, New Zealand and Australia. It was renamed 'Huxley' in England and was popular until 1953. Ettersburg 80 was extremely drought resistant, of high fresh and processing quality, because of the solid bright red color. Other outstanding Etter cultivars were 'Ettersburg 121', 'Fendalcino' and 'Rose Ettersburg'. While his releases were very successful as cultivars, their greatest lasting impact was as breeding parents. Most California cultivars (and many others) have an Ettersburg cultivar in their background (Darrow 1966; Sjulin and Dale 1987).

In the middle of the 20th Century, a number of particularly successful breeding programs emerged in Scotland, England, Germany and Holland. In Scotland, Robert Reid developed a series of red stele resistant cultivars utilizing American 'Aberdeen' as a source of resistance. His cultivar 'Auchincruive Climax' dominated acreage in Great Britain and northern Europe until its demise due to June yellows in the mid-1950's. In England, D. Boyle produced a large series of cultivars with the prefix 'Cambridge'. 'Cambridge Favorite' (1953) became the most important of the group and dominated the acreage in Great Britain by the 1960's.

In Germany, R. von Sengbusch's produced a 'Senga' series, of which 'Senga Sengana' (1954) became paramount. 'Senga Sengana' was widely planted for its processing quality and is still important in Poland and other eastern European countries. In the Netherlands, H. Kronenberg and L. Wassenaar's released several cultivars, of which 'Gorella' (1960) made the greatest impact. It was noted for its size, bright red glossy skin and red flesh. B. Meulenbroek who followed in this program released 'Elsanta' (1981), considered the ideal fresh market cultivar for its bright color, flavor and regular size.

Many breeding advances in the eastern United States have come from the U.S. Department of Agriculture (Hancock, 1999). George Darrow at Beltsville, Maryland, developed 'Blakemore' that became the major southern US cultivar in the mid-1930's, and 'Fairfax' was widely planted in the middle of this century from southern New England to Maryland and westward to Kansas. These two cultivars were used extensively in breeding, finding their way into the ancestry of a diverse array of cultivars grown in all parts of the US. Other important releases from Darrow were 'Pocahontas', 'Albritton', 'Surecrop' and 'Sunrise'. D. H. Scott, A. D. Draper and G. J. Galletta followed Darrow and released 'Redchief' (1968), 'Earliglow' (1975), 'Allstar' (1981), and 'Tribute' and 'Tristar' (1981). Many of these cultivars are still grown today, and the breeding program is still active. The current goal is year-round production of flavorful, disease-resistant varieties. 'Tribute' and 'Tristar' were the first day-neutrals widely grown in the eastern US.

An active USDA breeding program has also been conducted at Corvallis, Oregon, initially by Darrow, G.F. Waldo and F.J. Lawrence, and now C. Finn. Some of the more important cultivars emerging from this program were 'Siletz' (1955), 'Hood' (1965), and 'Tillamook' (2004). 'Hood' is considered the premier berry for processing.

Several other state and federal supported programs have released important cultivars in the USA and Canada. Some of the most significant ones from the USA were 'Honeoye' and 'Jewel' (New York), 'Raritan' (New Jersey) and 'Sweet Charlie' (Florida). The predominant cultivar in the Pacific Northwest from the 1970s to early 2000s was 'Totem' developed by Agriculture and Agri-Food Canada in British Columbia (Daubeny, 1971). From Nova Scotia came 'Bounty', 'Glooscap' and 'Kent'. H. Thomas and E. Goldsmith of the University of California released the important cultivars 'Lassen' and 'Shasta' in 1945. 'Shasta' was widely grown in the central coast of California in the 1950's and 1960's because of its large size, firmness and long season. 'Lassen' was grown extensively in southern California about the same period, prized for its short rest period and high productivity. R. Bringhurst and V. Voth took over the California-Davis program in the 1950's and generated a succession of internationally important, Mediterranean adapted cultivars, including 'Tioga' (1964), 'Tufts' (1972), 'Aiko' (1975), 'Pajaro' (1979), 'Chandler' (1983), 'Selva' (1983), 'Camarosa' (1992) and 'Seascape' (1991). D. Shaw and K. Larson released the day-neutrals 'Diamante,' 'Albion,' 'Monterey,' 'Portola,' and 'San Andreas' from this program.

Florida has a significant strawberry breeding and production industry, a distant second to that of California, with notable cultivars including 'Strawberry Festival' and 'Florida Radiance'. This breeding program is perhaps the best-supported public strawberry breeding program in the US with professional support in the fields of genomics, horticulture, and pathology, in addition to unprecedented support from Florida growers.

Many private companies have strawberry breeding programs with internationally coordinated production and marketing of their product.

Cultivar life spans

In most cases, if plant material from the wild is incorporated into strawberry breeding efforts, about 40 years of crossing, selection and testing is required prior to the production of a cultivar-level release, four times what is expected from elite-by-elite crosses. Most breeding programs work under long term objectives, preparing multiple penultimate releases from advanced breeding lines without returning to the incorporation of new wild germplasm. Frequently one breeder will make a cross and his/her successor will evaluate and make the final release. Sometimes breeding programs will share advanced lines with the consideration of mutual benefit when a selection is successful. In some cases, germplasm enhancers work with wild material and breed and select for "germplasm releases," after which breeders work from that release to develop advanced lines and cultivars.

Some cultivars do not do well after 1 to 5 years after release and are essentially "lost" from production nursery lists. Others survive 40 or 60 years. In the private sector, the life span of a successful strawberry cultivar is seldom longer than the length of a US plant patent, which is 20 years. The ratio of successful releases to total releases seems to be about 1/5 for per breeding program. Some older cultivars are tried in another geographic or climatic niche and then have a renewed life span of several decades. The following table includes some examples of "life spans" for a few publicly available strawberry cultivars (C. Finn and V. Whitaker, 2017, personal communication).

Cultivar	**Life Span**	**Location Released**
Hood	1964 – strong until present in Northwestern production	Oregon
Totem	1971 – strong until present in Northwestern production	BC, Canada
Rainier	1972 – strong until present in Northwestern production	Washington
Earliglow	1975 – strong until present in Eastern production	Beltsville, MD
Florida Radiance	2008 – present	Florida
Honeoye	1979 – strong until present in Northeastern production	New York
Tristar/Tribute	1981 – strong until present in Eastern production	Beltsville, MD

Allstar	1981 – strong until present in Northeastern production	Beltsville, MD
Chandler	1983 – still strong in Southeastern US	California
Jewel	1987 – strong until present in Northeastern production	New York
Camarosa	1993 – strong in Southeastern US and Internationally; no longer produced in California	California
Sweet Charlie	1994 – 2003 pushed out by Festival	Florida
Puget Reliance	1995 – strong until present in Northwestern production	Washington
Diamante	1996-2006 pushed out by Albion	California
Strawberry Festival	2000 – 2015	Florida
Tillamook	2004 – strong until present in Northwestern production	Oregon
Albion	2006 – 2016 largely replaced by 'Monterey' in California by 2017	California

Biotechnology in strawberry breeding

The potential for positive application of biotechnology to strawberry, as with other fruits and vegetables, is limited by the lack of public approval of breeding through genetic transformation (Hummer and Hancock 2009; Mezzetti 2009). The cost of research and development is high and regulatory approval is tortuous and prohibitive. Experimentation with perennials is expensive relative to annual crops. Thus, biotechnological application of molecular and genetic development of fruit crops through transgenes has not progressed since the early 1980s, when techniques first came available. Transformation of the octoploid strawberry has been well documented (Mezzetti 2009), but thus far for research purposes only. CRISPR/Cas9 gene editing is a new technology that may fare better with the public and face fewer regulations than transgenic technologies.

If transgenes or gene editing applications were accepted for strawberry cultivar development, many advances could be made efficiently including:

- Development of herbicide resistant cropping systems, which could help farmers who have lost methyl bromide
- Improved root rot resistance – also helpful for the loss of methyl bromide
- Enhanced flowering and fruiting
- Quality – maturation genes Tissue softening genes (for firmness)
- Carbohydrate development for flavor and processing quality
- Disease and pest resistances
- Cold hardiness
- Parthenocarpic fruiting

Several obstacles work against the acceptance of transgenic strawberries. The global economic value of this fruit crop (while high per acre) is small in total because much fewer acres are planted than that of agronomic crops. As a result, governments are not flocking to support this technology, and private stimulus is modest. The fruit industry has been reluctant to introduce products with potential negative backlash from people leery of consuming transgenic crops.

A second obstacle is the tendency of strawberries to be outcrossing. Their flower is open and insect pollination is common. In most regions where strawberries are cultivated, native relatives are widespread. These species relatives could hypothetically incorporate transgenes into wild biological systems. For this reason, release of transgenic strawberries will require more scrutiny and in depth ecological surveys than have been performed in other agricultural crops.

A strong influx of funds for thorough testing and environmental examination is needed before transgenic strawberries could be commercialized. Careful analysis of public perceptions regarding transgenic fruit is also required. Until this happens, transgenic strawberries will remain as a research tool without commercialization. Using marker-free transformation systems and targeted expression of transgenes will minimize public concern, but the fear of technology must be abated before transgenic strawberries will be commonly accepted.

2.2 Threats of genetic erosion in situ

Due to recent weather extremes, beach habitat is being challenged for the native North American beach strawberry, *Fragaria chiloensis*. Its habitat along the California coast is threatened in some locations.

The Chilean native strawberry has been used for food, drink, and ceremonial rites by Chilean native people for several centuries. Ecotypes of the species can be found in diverse soils and in variable climatic conditions (Hancock et al., 1999; Lavin et al. 2000). In the last 50 years this native strawberry has been increasingly displaced from its growing areas by the introduction of European and California cultivars of the commercial strawberry (Lavin and Maureira, 2000). The natural habitats have also been disrupted by humans. This has restricted the availability of germplasm and has put the preservation of the Chilean ecotypes at risk. Even though commercial strawberries have higher yields, the fruit quality is not as diverse in flavor components or aromas as the native Chilean fruit. The culture of the white fruited form is now restricted to small plantings with coastal influence (Retamales et al., 2005). Volcanic action has also destroyed some native habitat for strawberries in Chile.

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

2.3.1 Biotic (diseases, pests)

Virus diseases are very important in strawberry (Appendix Table 2), motivating extensive testing and certification programs in the nursery industry. Martin (2004) has recommended procedures for detection of strawberry viruses. These tests include bioassays on indicator plants, sap and graft inoculation, enzyme linked immunosorbent assay, double-stranded RNA detection and polymerase chain reaction (PCR).

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

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

Fungal and bacterial diseases

Common insects and diseases should be managed to maintain healthy vigorous plants. To reduce the risk of soil borne pathogens, such as red stele caused by *Phytophthora fragariae* var. *fragariae* Hickman, runners should be propagated and the mother plant destroyed. Diekmann et al. (1994) describes symptoms, host range, geographical distribution, biology and transmission of the disease. Leaf spot (*Alternaria*), anthracnose (*Colletotrichum spp.*), fusarium wilt, verticillium wilt, phytophthora crown rot (*Phytophthora cactorum*, bacterial leaf spot (*Xanthomonas fragariae)*, and strawberry black root rot are described. Since 2013, charcoal rot, *Macrophomina phaseolina*, has become a problem in California where previous fumigants are no longer available, as well as in Florida where the incidence of this disease continues to increase as of 2017. *Fusarium oxysporum*, verticillium wilt, powdery mildew (*Podosphaera aphanis*), *Rhizopus* and *Botrytis* also continue to be problems. Fungicide resistance is now very common in *Botrytis* isolates in Florida.


Photos of *Macrophomina* in strawberry by Steve Koike, University of California, Cooperative Extension.

Information on California cultivars from Steve Koike, July 2013.

Cultivar	Macrophomina	Fusarium
Chandler	Resistant	Susceptible
Florida Radiance	Moderately resistant	Susceptible
Monterey	Susceptible	Resistant
San Andreas	Susceptible	Resistant
Seascape	Resistant	Susceptible
Strawberry Festival	Susceptible	Resistant
Ventana	Susceptible	Resistant

Insect and arthropod pests

Insects and mites are major threats to cultivated strawberry plants. Nearly 200 species of insects and mites have been reported to infect strawberry plants in North America (Maas, 1984). Not only do they cause direct plant damage, but they can also vector viruses and other diseases. Suggested control measures for arthropod pests combine cultural, biological and chemical methods in an integrated plant production approach. New chemistries have been developed so that biologically safer and environmentally-conscious products are available for control measures. At times, however, genebanks must be prepared to use danger-labeled chemicals to prevent the entry of an exotic disease or pest. In addition, resistance of two-spotted mites to miticides has been observed in Florida, as well as resistance of Western flower thrips to certain insecticides.

Cyclamen mites can be particularly problematic in the maintenance of strawberry plants. To control cyclamen mites, runners are treated in hot water. Runners are held in a 50 °C water bath with a silicone surfactant (100 ppm) for 5 to 10 min, then placed in a cool water rinse. About 80% of runners survive this treatment.

Spotted wing drosophila (*Drosophila suzukii*) is now present in North America and constitutes a major new threat. It prefers soft fruit for oviposition and can causes substantial losses in late-ripening berry crops. Strawberries ripen early and are not bothered in some regions of the US, however, late crops and remontant types are subject to SWD damage.

A number of species of root weevils are also important pests in strawberry. The black vine weevil, *Otiorhynchus sulcatus* Fabricius, is probably the most widespread and problematic of these. Adults feed on the foliage, while the larvae can do extensive damage to the root system. Shanks et al. (1984) and Shanks and Doss (1986), identified germplasm with some resistance to adult black vine weevil, but which were still susceptible to the larval stage, where most of the damage occurs. The cultivar 'Stolo' and its parent 'Whonnock' have strong resistance to feeding by larvae of the black vine weevil and have also been reported to be tolerant to feeding by obscure root weevil (*Sciopithes obscurus*, Horn) and strawberry root weevil (*O. ovatus*) larvae (Kempler et al., 2011).

Strawberry crown moth (*Synanthedon bibionipennis* Boisduval) can be an important pest in western North America. The young larvae feed on the outside of the crown before boring deeper to feed and overwinter. They continue to feed for a short time the following spring prior to pupating. The recommended chemical control, chlorpyrifos, was the subject of a decade-long petition to ban due to adverse environmental and human health effets. In 2017, the EPA rejected the petition and chlorpyrifos is still in use, but it may be targeted for deregistration again in the future. Casual observations indicate that, ORUS 3185-1, a *Fragaria virginiana* accession collected from the North Cascades region of Washington State for its remontancy, has a degree of resistance or tolerance to strawberry crown moth which it passes on to its progeny.

2.3.2 Abiotic (environmental extremes, climate change)

Abiotic stresses can be increased by factors as diverse as climate change and market dynamics. Weather extremes are threatening *F. chiloensis* in some coastal locations of California. Meanwhile, the demand for locally-produced fruit during the summer months is motivating the development of day-neutral cultivars for regions with warm summers (Michigan, Ontario, eastern seaboard) that have greater heat tolerance for floral initiation. Meanwhile, earlier planting in Florida in the month of September due to the demand for early fruit is also motivating the development of adapted cultivars with floral heat tolerance.

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

The value of U.S. Strawberry production ballooned from approximately $1 billion in 2000 to approximately 2.4 billion in 2010 (see Section 1.3). This has been accompanied by increases in acreage in some regions, for example, in Florida, where acreage has nearly doubled since 2000. These trends are the result of increased quality and increased consumer demand over this period. In order to keep pace, breeders will need to continue to maintain and increase yields and quality while also maintaining and increasing disease resistances due to the loss of methyl bromide.

2.3.4 Dietary (inability to meet key nutritional requirements)

Fresh strawberries are a low-calorie source of Vitamin C, with 100 g of fresh berries containing, on average, 32 kcal and 58.8 g total ascorbic acid (USDA-ARS, 2010). The strawberry fruit contains thousands of metabolites, which strongly impact consumer’s senses and health (Schwab et al. 2009). Most analytical biochemical studies of strawberry fruits have relied on specific extraction/separation methods to identify and quantify targeted compounds and interests. Strawberry flavor is complex. One comprehensive non-targeted metabolic analysis of strawberry identified 5,844 unique spectrophotometric peaks by analyzing fruits at four developmental stages (Aharoni et al. 2002). Many artificial strawberry flavors use only a handful of the top compounds to cheaply imitate the true constituents, and humans recognize the difference. Schwab et al. (2002) summarizes the genetic work concerning volatile and polyphenolic compounds including metabolic routes and associated genetic mechanisms. The wild species are rich with flavor compounds, some of which have been lost during domestication.

Fruit firmness, a genetically complex trait, has been a focal point of many large breeding programs during the past 50 years. The increase in firmness provided through breeding has provided the strawberry industry with the capability to move fruit to the far reaches of the globe, and capitalize on strawberry as a product. Breeding for firmness is a difficult task, complicated as Salentjn et al. (2003) has pointed out, because of the inverse correlation between firmness and flavor emissions. Developing fruit with flavor and firmness is the new dictum of commercial breeding programs.

Strawberries are rich in Vitamin C (ascorbic acid) and ellagic acid. Both compounds have a significant role in promoting human health. The amount of ellagic acid varies between cultivars and between different plant parts. Some breeding programs monitor the levels of these compounds to ensure maintenance of these already high levels of beneficial phytochemicals. Other breeding programs favor development of cultivars that support year-round production and have fruit with good flavor in order to encourage increased consumption of an already nutritious fruit. Colquhoun et al. (2012) described consumer preferences for sweetness and complex flavor in strawberry fruit. The health benefit of the strawberry was not found to be as influential a selection criterion as was taste.

Allergens

As in other fruits, strawberries contain proteins which can cause allergic reactions in humans (Schwab et al. 2009). The strawberry FRA a 1 protein family is homologous to the major birch pollen allergen Bet v 1 and includes several IgE-binding peptides with small intra- and inter-genotype sequence variability, though subjected to post-translational modifications.

Profilins and lipid transfer proteins (LTPs), found in strawberries, are also represented in other cultivated crops in the rose family. Strawberry LTP and profilins are expressed in many fruit tissues and accumulate with abiotic stress (Yubero-Serrano et al. 2003). Some studies have found that strawberry LPT had lower allergenicity than apple or peach homologs. The strawberry allergens are in the range suited for immunotherapy (Zuidmeer et al. 2006).

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)

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

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 strawberry genebank collection is kept *ex situ* in Corvallis, Oregon. Back-up seed of species have been sent to NCGRP in Ft. Collins, Colorado, and to the Global Seed Vault in Svalbard, Norway. *In situ* reserve agreements have not been established in the United States for *Fragaria*. This genus would be a good candidate to consider *in situ* conservation within the United States.

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 which contain specific traits of interest and elite wild accessions.

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

The available *Fragaria* clonal collection at the NCGR-Corvallis is listed in Appendix Table 3 or can be obtained by searching GRIN accession text query entering: "*Fragaria* cultivar".

The *Fragaria* species collection at the NCGR-Corvallis is listed in Appendix Table 4).

The collection includes at least single representatives of each of the world strawberry taxa (found in Appendix table 1).

3.1.2 Genetic coverage and gaps

Clonal holdings

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

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

Belle de Meau	Cyrano de Bergerac	Filbasket
Chief Bemidji	Deutsch Evern	Filbert Pine

Fraiser Louis Gauthier	Lester	Sans filets rouge
Givon's Late Prolific	Missionary	Selecta
Jeanne d'Arc	Red Cross	Sparkle
Klonmore	Redrich	Suwanee
La Perle	Reine des Vallees	Waterloo
La Sans Rival = Sans Rival	Reward	
Laxton's Latest	Royal Sovereign	

The collection of diploid, tetraploid and hexaploid *Fragaria* is of secondary importance to the octoploids. However, we need to get a better representation of the Asian diploids and tetraploids, as only a few clones of each is currently represented in the national germplasm collection, and these species will ultimately be the key to determining evolutionary relationships in the genus.

2. Domestic Collection Gaps.

- Northern reaches in Alaska; Unalaska and Archipelago
- Hawaii – on Big Island – need to work out agreement for in situ/ex situ preservation with US National Park Service. Plants are on Park Service land.
- Midwestern United States, and the southwestern United States below Colorado.
- Isolated *F. vesca* occurs in Steens Mountain, Oregon, near Fir Creek, in remnant white fir stands which have been there preglaciation. Prior to the Pleistocene the Steens likely had a conifer forest where *Fragaria* could have been in the understory.
- Ochoco Mountains east into Blue Mountains to the Wallowa Mountains in Oregon. Strawberry Mountain is on the south end of the Blue Mountains, but this was not seriously glaciated
- The Wallowa Mountains had extensive glaciations so that there is Holocene (new habitat) similarto decaploid habitat in the Cascade Mountains (7-8,000' elevation). Possibly there was new available habitat for strawberries as the ice retreated. Columbia River flows were likely during the Pliocene, pre-glaciation, which was very old and geo-ecology
- Olympic Mountains, Washington State, need additional collection
- Wasatch Mountains in Utah need additional collection
- Ruby Mountains, Nevada, need additional collection
- Kaibab on north side of Grand Canyon, should be collected – big bend because of the Kaibab plateau. – National Park 78 miles from south rim view point
- San Francisco Peak by Flagstaff, Arizona, should be collected.

List of Designates Primary, Secondary, and Tertiary Crop Wild Relatives

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

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: STRAWBERRY

http://www.ars-grin.gov/~sbmljw/cgi-bin/cwrelative.pl?crop=strawberry&prim=on&second=on&tert=on&graft=on

Crop taxa:

1. ***Fragaria ×ananassa* Duchesne ex Rozier – strawberry**
2. ***Fragaria ×ananassa* Duchesne ex Rozier nothosubsp. *ananassa* – strawberry**

Crop wild relatives:

Primary

1. *Fragaria ×ananassa* Duchesne ex Rozier nothosubsp. *cuneifolia* (Nutt. ex Howell) Staudt — [References]
2. *Fragaria chiloensis* (L.) Mill. — [References]
3. *Fragaria chiloensis* (L.) Mill. subsp. *chiloensis* forma *chiloensis* — [References]
4. *Fragaria chiloensis* (L.) Mill. subsp. *lucida* (E. Vilm. ex Gay) Staudt — [References]
5. *Fragaria chiloensis* (L.) Mill. subsp. *pacifica* Staudt — [References]
6. *Fragaria chiloensis* (L.) Mill. subsp. *chiloensis* forma *patagonica* Staudt — [References]
7. *Fragaria chiloensis* (L.) Mill. subsp. *sandwicensis* (Decne.) Staudt — [References]
8. *Fragaria virginiana* Mill. — [References]
9. *Fragaria virginiana* Mill. subsp. *glauca* (S. Watson) Staudt — [References]
10. *Fragaria virginiana* Mill. subsp. *grayana* (Vilm. ex J. Gay) Staudt — [References]
11. *Fragaria virginiana* Mill. subsp. *platypetala* (Rydb.) Staudt — [References]
12. *Fragaria virginiana* Mill. subsp. *virginiana* — [References]

Secondary

1. *Fragaria cascadensis* K. E. Hummer — [References]
2. *Fragaria iturupensis* Staudt — [References]

Tertiary

1. *Fragaria bucharica* Losinsk. — [References]
2. *Fragaria chinensis* Losinsk. — [References]
3. *Fragaria corymbosa* Losinsk. — [References]

4. *Fragaria daltoniana* J. Gay — [References]
5. *Fragaria hayatae* Makino — [References]
6. *Fragaria iinumae* Makino — [References]
7. *Fragaria mandshurica* Staudt — [References]
8. *Fragaria moschata* Weston — [References]
9. *Fragaria moupinensis* (Franch.) Cardot — [References]
10. *Fragaria nilgerrensis* Schltdl. ex J. Gay — [References]
11. *Fragaria nilgerrensis* Schltdl. ex J. Gay var. *mairei* (H. Lév.) Hand.-Mazz. — [References]
12. *Fragaria nilgerrensis* Schltdl. ex J. Gay var. *nilgerrensis* — [References]
13. *Fragaria nipponica* Makino — [References]
14. *Fragaria nipponica* Makino subsp. *chejuensis* Staudt & Olbricht — [References]
15. *Fragaria nipponica* Makino subsp. *nipponica* — [References]
16. *Fragaria nipponica* Makino subsp. *yakusimensis* (Masam.) Staudt & Olbricht — [References]
17. *Fragaria nubicola* (Hook. f.) Lindl. ex Lacaita — [References]
18. *Fragaria orientalis* Losinsk. — [References]
19. *Fragaria pentaphylla* Losinsk. — [References]
20. *Fragaria tibetica* Staudt & Dickoré — [References]
21. *Fragaria vesca* L. — [References]
22. *Fragaria vesca* L. subsp. *vesca* forma *alba* (Ehrh.) Staudt — [References]
23. *Fragaria vesca* L. subsp. *bracteata* (A. Heller) Staudt forma *albida* Staudt — [References]
24. *Fragaria vesca* L. subsp. *americana* (Porter) Staudt — [References]
25. *Fragaria vesca* L. subsp. *bracteata* (A. Heller) Staudt forma *bracteata* (A. Heller) Staudt — [References]
26. *Fragaria vesca* L. subsp. *bracteata* (A. Heller) Staudt — [References]
27. *Fragaria vesca* L. subsp. *californica* (Cham. & Schltdl.) Staudt — [References]
28. *Fragaria vesca* L. subsp. *bracteata* (A. Heller) Staudt forma *helleri* (Holz.) Staudt — [References]
29. *Fragaria vesca* L. subsp. *vesca* forma *roseiflora* (Boulay) Staudt — [References]
30. *Fragaria vesca* L. subsp. *vesca* forma *semperflorens* (Duchesne) Staudt — [References]
31. *Fragaria vesca* L. subsp. *vesca* — [References]
32. *Fragaria viridis* Weston — [References]

Gaps in Foreign Species holdings

Species representatives are especially needed from across Canada, Chile, Ecuador, Peru, China, Korea, India, Bhutan, Russia (Far Eastern Territories including: Kurile Islands, Kamchatka, Amur) Japan, India, and Nepal. In addition, a number of valuable land races of *F. chiloensis* still need to be collected in Chile, Peru and Colombia. *Fragaria virginiana* needs to be collected across Canada. Particular attention should be given to Northwestern and Northeastern Canada.

3.1.3 Acquisitions

Plants

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

Permits can be obtained through application the USDA APHIS PPQ website http://www.aphis.usda.gov/plant_health/permits/

APHIS works with the Oregon Department of Agriculture (ODA) to provide inspection of plant material. Specifically, strawberry plants that are brought into the US must be inspected, grown over copper sulfate where any excess water is contained, until runners form. Runners can be released from quarantine and the mother plant is destroyed. This is to prevent strains of red stele (*Phytophthora fragariae*) from entering the country from foreign sources.

Seeds

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

3.1.4 Maintenance

Clonal storage

Cultivars, selections, and species core plants are maintained in two containers for each genotype. Non-core species plants are maintained in one container.

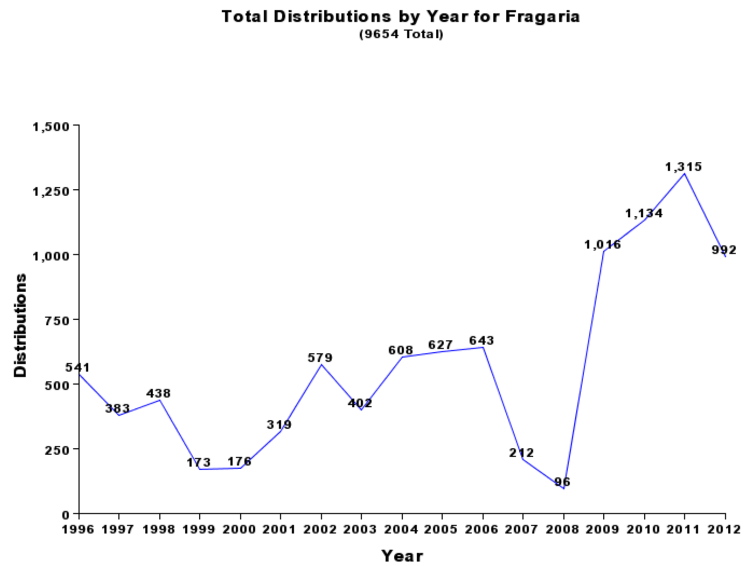
Seed storage

After extraction, seeds are put into manila seed envelops and then into plastic-aluminum envelops for storage in -20^{o}C chest freezers.

3.1.5 Distributions and outreach

Strawberries are distributed as crown divisions, runners, tissue cultures, pollen, flowers, or seed. Usually, for plant requests, strawberry runners are available for distribution in mid-July. Crown divisions can be available November through January during the dormant season. Cold stored tissue cultured plants in plastic packets or seeds can be distributed any time of year.

Since 1981, when the NCGR was dedicated, to 31 May 2013, more than 15,000 strawberry accessions have been distributed. The most distributed species was *F.* ×*ananassa* at 7,600 accessions during that time. The top 10 most requested strawberry accessions were: 'Marshall', 'Fairfax', *F. iturupensis*, 'Weisse Anasa', 'Capron' (*F. moschata*), 'Profumata di Tortuna' (*F. moschata*), 'Earliglow', 'Allstar', 'Yellow Wonder' (*F. vesca*), and 'Blakemore'. In addition, the strawberry virus positive collection were well requested by pathologists for virus testing procedures. Annual strawberry distribution counts are provided below.



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
Strawberry catalog link: https://www.ars.usda.gov/Main/docs.htm?docid=11324

Passport information
Genotypic characterization data
Phenotypic evaluation data

As of 1 October 2013, information will be 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 USDA NIFA Specialty Crop Research Initiative RosBREED to link economically useful genes, such as those for resistance to red stele (*Phytophthora fragariae*) and continuous or repeat blooming, with specific genotypes in the collection.

3.3.1 Future Goals and emphases

- Obtain wild octoploid strawberries with resistance to root rots
- Obtain wild octoploid strawberries with resistance to foliar and fruit diseases
- Obtain primary, secondary, tertiary crop wild relatives with high fruit qualities
- Obtain wild octoploid strawberries that are continuous blooming
- Obtain heritage cultivars from the US
- Obtain heritage cultivars from Europe

- Obtain wild strawberries from Asia to Northwestern America that would be intermediate in the development of the North American octoploid and decaploid strawberries.

3.3.2 Significant accomplishments

- Significant plant collections from Chile in 1990 and 1991
- Significant plant collections from the US in multiple collecting trips over 30 years. Discovery that *F. iturupensis* Staudt is decaploid ($2n = 10x = 70$).
- Discovery and naming of *F. cascadensis* Hummer, also decaploid. Species native to Oregon high peaks.
- Conservation of heritage strawberries dating back to the early 1900s.
- Conservation of significant genotypes from Dr. Royce Bringhurst, strawberry breeder at University of California, Davis, from 1960s to 1990s.
- Evaluated strawberries for *Verticillium* resistance in New Hampshire
- Evaluated strawberries for nematode resistance in Oregon
- Evaluated strawberries for cold hardiness in Minnesota
- Evaluated strawberries for multiple diseases and for flowering with no chilling in Florida
- Evaluated of *Fragaria vesca* (diploid strawberry) germplasm for remontancy and thermotolerance
- Evaluated the *Fragaria* Supercore Collection for Powdery Mildew and Spider Mite Resistance
- Evaluated new Asian *Fragaria* accessions for cold hardiness and leaf disease resistance
- Evaluated wild diploid and octoploid strawberry germplasm for Verticillium wilt resistance
- Evaluated strawberry germplasm for resistance to anthracnose and bacterial angular leaf spot diseases
- Evaluated the strawberry core for nematode resistance
- Evaluated the strawberry core at multiple locations for three years
- Evaluated strawberry germplasm for disease resistance (particularly to *Xanthomonas*)

3.4 Curatorial, managerial and research capacities and tools

3.4.1 Staffing

0.1 FTE Cat. 4 support scientist Curator
0.1 FTE Cat. 1 research Scientist Plant Physiologist (tissue culture, cryogenic research)
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- flower removal, plant management
1.3 FTE total labor for strawberry efforts

3.4.2 Facilities and equipment ft^2 m^2

2.5 Screenhouses for strawberry only	6,000	700
(below only 1/10 for strawberry)		
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)
- Plant propagation equipment (mistbed, propagation houses, quarantine facility)
- Field propagation

3.5 Fiscal and operational resources

Federal funding to support federal *Fragaria* germplasm management at NCGR-Corvallis: FY 2013 – $144,400.

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

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)

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

5. Prospects and future developments

6. References

Aharoni A, de Vos RCH, Verhoven HA, Maliepaar CA, Kruppa G, Bino R, Goodenowe DB (2002) Nontargeted metabolome analysis by use of Fourier Transform Ion Cyclotron Mass Spectrometry OMICS 6:217-234.

Barrit BH, and Shanks Jr, CH (1980) Breeding strawberries for resistance to aphids *Chaetosiphon fragaefolii* and *C. tomassi*. HortScience 15:287–288.

Bentvelsen, GCM., Bouw, E, and Veldhuyzen van Zanten, JE (1997) Breeding strawberries *(Fragaria×ananassa* Duch.) from seed. Acta Hortic. 439:149–154 http://dx.doi.org/10.17660/ActaHortic.1997.439.18.

Colquhoun, TA, LA. Levin, H R. Moskowitz, VM. Whitaker, DG Clark, and KM Folta (2012) Framing the perfect strawberry: a consumer assisted selection of fruit crops. J. Berry Res. 2:445-61.

Darrow G (1966) The Strawberry: History, Breeding and Physiology. Holt, Rinehart and Winston, New York, Chicago, and San Francisco. 447 pp.

Daubeny, HA (1971). Totem strawberry. Canadian J Plant Sci. 51:176-177

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

Duchesne AN (1766) Histoire naturelle des Fraisiers. Paris.

Faedi, W., Mourges F, Rosati C (2002) Strawberry breeding and varieties: Situation and perspectives. Acta Hort 567: 51-59.

Food and Agriculture Organization of the United Nations (2017) FAOSTAT Statistics Database. http://www.fao.org/faostat/en/#data/QC accessed 19 October 2017.

Fernandez, G.E., L.M. Butler, and F.J. Louws (2001) Strawberry growth and development in an annual plasticulture system. HortScience 36:1219–1223.

Finn, C.E., B. Yorgey, B.C. Strik and P.P. Moore (2004) 'Tillamook' and 'Pinnacle' strawberries. HortScience 39:1487-1489.

Fletcher SW (1917) The strawberry in North America; History, origin, botany and breeding. The Macmillan Company, New York 234 pp.

Hancock, J.F (1999) Strawberries. Crop Production Science in Horticulture Series, No. 11. CABI Publishing, Wallingford, UK.

Hancock, J.F. 2006**.** California public strawberry breeders: A perfect marriage of genetics and culture. HortScience 41: 12-13.

Hancock, JF, Luby J, Dale A, Callow PA, Serce S, El-Shiek A (2002) Utilizing wild *Fragaria virginiana* in strawberry cultivar development: Inheritance of photoperiod sensitivity, fruit size, gender, female fertility and disease resistance. Euphytica 126:177-184

Hedrick, U.P (1919) Sturtevant's Edible Plants of the World. Dover Publications, New York (formerly published in 1919 by J.B. Lyon Company, Albany as Sturtevant's Notes on Edible Plants).

Hughes BR, Fisher P, Jamieson AR (2013) Comparison of Nine Clones of 'Jewel' Strawberry in Ontario and Nova Scotia, International Journal of Fruit Science, 13:175-183.

Hultén, E. (1968) Flora of Alaska and Neighboring Territories: A manual of the Vascular Plants. Stanford University Press, Stanford, CA.

Hummer K.E. (ed.) (2008) Global conservation strategy for *Fragaria* (strawberry). Scripta Hort #6, 87 pp. Leuven, Belgium.

Hummer, K.E (2009) Global conservation of strawberries: a strategy is formed. Acta Hort 842:577-580.

Hummer, K. (2012) *Fragaria cascadensis* Hummer. J. Bot. Res. Inst. Texas. 6(1): 9 – 15.

Hummer, K.E, Hancock JH (2009) Strawberry genomics: Botanical history, cultivation, traditional breeding, and new technologies, chapter 11, In: Folta K, Gardiner (eds.) Genetics and Genomics of Rosaceae. Springer, New York, pp 413-435.

Hummer, K, Nathewet P, Yanagi T (2009) Decaploidy in *Fragaria iturupensis* (Rosaceae). Am J Bot 96(3):713-716

Hummer, K.E., Bassil N, and Njuguna W 2011. *Fragaria*. Chapter 2 in: (C. Kole, ed.) Wild Crop Relatives: Genomics and Breeding Resources, Temperate Fruits. Springer WCR Series Vol 6: 17-44.

Kempler, C., H.A. Daubeny, B. Harding, L. Frey, T.E. Baumann, C.E. Finn, S. Khanizadeh, A.R. Jamieson, K. MacKenzie, P.P. Moore, and M. Sweeney (2011) 'Stolo' Strawberry. HortScience 46(7):1046-1048.

Lawrence, F.J, Galletta GJ, Scott DH (1990) Strawberry breeding work of the United States Department of Agriculture. HortScience 25:895-896.

Lei J, Li Y, Du G, Dai H, Deng (2005) A natural pentaploid strawberry genotype from the Changbai Mountains in northeast China. HortScience 40:1194-1195.

Lewers KS, Fleisher DH, Daughtry CST (2017) Low tunnels as a strawberry breeding tool and season-extending production system. International Journal of Fruit Science 17:233-258.

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

Martin, R. R. and I. E. Tzanetakis. 2006. Characterization and recent advances in detection of strawberry viruses. Plant Dis. 90(4):384-396.

Maas, J.L. 1984. Compendium of strawberry diseases. American Phytopathological Society. St. Paul Mn.

Mezzetti B (2009) GMO Strawberry: Methods, risk and benefits. Chapter 23, pp. 487 – 506 in: K. Folta and S. Gardiner (eds.) Genetics and Genomics of Rosaceae, Plant Genetics and Genomics: Crops and Models 6. Springer Science+Business. New York

Mitcham E. (2002) Strawberry. In: The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Crops, USDA Agric. Hdbk No. 66, Gross, K.C., C.Y. Wang, and M. Saltveit (eds.), 8 Nov. 2002. http://www.ba.ars.usda.gov/hb66/index Accessed 9 August 2013.

Oda Y, Nishimura K (2009) 'Ichigo' – Japanese name of strawberry- it's origin and historical change of phonogram for strawberry in Japan. Acta Hort 842:611-618.

Retamales JB, Caligari PDS, Carrasco B, and Saud G. (2005) Current status of the Chilean native strawberry and the research needs to convert the species into a commercial crop. HortScience 40:1633-1644.

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

Salentjn, E. Aharoni A, Schaart G. Boone Mj, and Krens FA (2003) Differential gene expression analysis of strawberry cultivars that differ in fruit firmness. Physiol Plant 118:571-578

Spigler, R., K. Lewers, A. Johnson, and T.-L. Ashman (2010) Comparative mapping reveals autosomal origin of sex chromosome in octoploid *Fragaria virginiana*. J Hered 101:S107–S117.

Shanks, C.H., and R.P. Doss (1986) Black vine weevil (Coleoptera: Curculionidae) feeding and oviposition on leaves of weevil-resistant and –susceptible strawberry clones presented in various quantities. Environ Entomol 15:1074-1077.

Shanks, H.C., D.L. Chase, and J.D. Chamberlain (1984) Resistance of clones of wild strawberry, *Fragaria chiloensis,* to adult *Otiorhynchus sulcatus* and *O. ovatus* (Coleoptera: Curculionidae) Environ Entomol 13:1042-1045.

Sjulin, T.M. 2006. Private strawberry breeders in California. HortScience 41:17-19.

Staudt G (1959) Cytotaxonomy and phylogenetic relationships in the genus *Fragaria* Proc IX Intern Bot Congr 2:377.

Staudt G (1962) Taxonomic studies in the genus *Fragaria*: Typification of *Fragaria* species known at the time of Linnaeus. Can J Bot 40:869-886.

Staudt G (1989) The species of *Fragaria*, their taxonomy and geographical distribution. Acta Hort 265:23-33.

Staudt G (2003) Notes on Asiatic *Fragaria* species: III. *Fragaria orientalis* Losinsk. and *Fragaria mandshurica* spec. nov. Bot Jahrb Syst 124(4):397-419.

Staudt G (2005) Notes on Asiatic *Fragaria* species: IV. *Fragaria iinumae*. Bot Jahrb Syst 126(2):163-175.

Staudt G (2006) Himalayan species of *Fragaria* (Rosaceae). Bot Jahrb Syst 126(4):483-508

Staudt G, Dickorè WB (2001) Notes on Asiatic *Fragaria* species: *Fragaria pentaphylla* Losinsk. and *Fragaria tibetica* spec. nov. Bot Jahrb Syst 123:341-354.

Staudt G, DiMeglio LM, Davis TM, Gerstberger P (2003) *Fragaria ×bifera*: Origin and Taxonomy. Bot Jahrb Syst 125:53-72.

Staudt G (1999a) Notes on Asiatic *Fragaria* species: *Fragaria nilgerrensis* Schltdl. ex J. Gay. Bot Jahrb Syst 121(3):297-310.

Staudt G (1999b) Systematics and geographic distribution of the American strawberry species: Taxonomic studies in the Genus *Fragaria* (Rosaceae:Potentilleae). Botany, vol 81. University of California Press, Berkeley, 162 pp.

Staudt G (2008) Notes on Asiatic *Fragaria* species V: *F. nipponica* and *F. iturupensis*. Bot Jahrb Syst 127(3):317-341.

USDA-Economic Research Service. 2012. Food availability (per capita) data system, August 2012.

USDA-Economic Research Service. 2016. Fruit and tree nuts outlook FTS-361, March 31, 2016.

USDA-Economic Research Service, *Fruit and Tree Nuts Outlook* FTS-341, March 26, 2010.

USDA-National Agricultural Statistics Service, Noncitrus Fruits and Nuts 2010 Summary, July 2011.

USDA-National Agricultural Statistics Service. 2015. Noncitrus fruits and nuts 2014 Summary, July 2015.

Wilhelm S, and Sagen JA (1974). *A History of the Strawberry*. University of California Division of Agriculture Pub. 4031. Berkeley CA.

Yubero-Serrano E, Moyano E, Medina-Escobar N, Munoz-Blanco J, Caballero J (2003). Identification of a strawberry gene encoding a non-specific lipid transfer protein that responds to ABA wounding and cold stress. J Exp Bot 54:1865-1877.

Zuidmeer L, Salentjin E, Rivas M, Mancebo E, Asero R, Matos C, Pelgrom K, Gilissen L, Van Ree R (2006) The role of profiling and lipid transfer protein in strawberry allergy in the Mediterranean area. Clin Exp Allergy 36:666-675.

7. Appendices

Table 1 *Fragaria* species, ploidy and distribution area.

F. bucharica Losinsk	2*x*	Western Himalayas
F. chinensis Losinsk[z]		China
F. daltoniana J. Gay		Himalayas
F. *hayatai* Staudt		Taiwan
F. innumae Makino		Japan
F. mandshurica Staudt		North China
F. nilgerrensis Schlect.		Southeastern Asia
F. nipponica Lindl.		Japan
F. nubicola Lindl.		Himalayas
F. pentaphylla Losinsk		North China
F. vesca L.		Europe, Asia west of the Urals, disjunct in North America
F. viridis Duch.		Europe and Asia
F. ×bifera Duch.		France, Germany
F. corymbosa Losinsk	4*x*	Russian Far East/ China
F. gracilis A. Los.		Northwestern China
F. moupinensis (French.) Card		Northern China
F. orientalis Losinsk		Russian Far East
F. tibetica Staudt & Dickoré		China
F. ×bringhurstii Staudt	5*x* (9*x*)	California
F. sp. nov[y]		China
F. moschata Duch.	6*x*	Euro-Siberia
F. chiloensis (L.) Miller	8*x*	Western N. America, Hawaii, Chile
F. iturupensis Staudt		Iturup Island, Kurile Island
F. virginiana Miller		North America
F. ×ananassa Duch. ex Lamarck		Cultivated worldwide
F. ×ananassa subsp. *cuneifolia*		northwestern N. America
F. iturupensis Staudt	10*x*	Iturup Island, Kurile Island
F. cascadensis Hummer		Oregon, United States
F. ×vescana R. Bauer & A. Bauer		Cultivated in Europe

[z]As proposed by Staudt 2008
[y]As proposed by Lei et al. 2005

Appendix Table 2. Viruses that infect strawberries (from Martin and Tzanetakis, 2006).

Virus name	Acronym	Mode of transmission	Genus	Laboratory detection[b]

Apple mosaic	ApMV	Pollen, Seed	Ilarvirus	ELISA, RT-PCR
Arabis mosaic	ArMV	Nematode, Seed	Nepovirus	ELISA, RT-PCR
Beet pseudo-yellows	BPYV	Whitefly	Crinivirus	RT-PCR
Fragaria chiloensis cyptic	FClCV	Unknown	Unknown	RT-PCR
Fragaria chiloensis latent	FClLV	Pollen, Seed	Ilarvirus	ELISA, RT-PCR
Raspberry ringspot	RpRSV	Nematode, Seed	Nepovirus	ELISA, RT-PCR
Strawberry chlorotic fleck	StCFV	Aphid	Closterovirus	RT-PCR
Strawberry crinkle	SCV	Aphid	Cytorhabdovirus	RT-PCR
Strawberry feather leaf	NA	Unknown	Unknown	NA
Strawberry latent	StLV	Unknown	Cripavirus	RT-PCR
Strawberry latent C	SLCV	Aphid	Nucleorhabdovirus	N
Strawberry latent ringspot	SLRSV	Nematode, Seed	Sadwavirus	ELISA, RT-PCR
Strawberry mild yellow edge	SMYEV	Aphid	Potexvirus	ELISA, RT-PCR
Strawberry mottle	SMoV	Aphid	Sadwavirus	RT-PCR
Strawberry necrotic shock	SNSV	Thrips, Pollen Seed	Ilarvirus	ELISA, RT-PCR
Strawberry pallidosis associated virus	SPaV	Whitefly	Crinivirus	RT-PCR
Strawberry pseudo mild yellow edge	SPMYEV	Aphid	Carlavirus	ELISA
Strawberry vein banding	SVBV	Aphid	Caulimovirus	PCR
Tobacco necrosis	TNV	Oomycete	Necrovirus	ELISA, RT-PCR
Tomato blackring	TBRV	Nematode, Seed	Nepovirus	ELISA, RT-PCR
Tomato ringspot	ToRSV	Nematode, Seed	Nepovirus	ELISA, RT-PCR

[a]NA Not Available, indicates the virus disease has been described in the literature but that the authors are unaware of a known isolate of the virus currently maintained in a collection.

[b]Detection methods listed do not include, sap inoculation, graft transmission or vector transmission to indicator plants.

Appendix Table 3. Available strawberry genotypes in the NCGR-Corvallis collection.

TAXON	Cultivar/ Selection	IVP	IVNO	IVS	PI	STATE	COUNTRY
Fragaria x ananassa	Aberdeen	CFRA	401	0.001	551630	New Jersey	United States
Fragaria x ananassa	Aberdeen	CFRA	401	0.002	551630	New Jersey	United States
Fragaria x ananassa	Acadia	CFRA	238	0.001	551607	Nova Scotia	Canada
Fragaria x ananassa	Addie	CFRA	967	0.001	552260		Italy
Fragaria x ananassa	Aiko	CFRA	68	0.001	551489	California	United States
Fragaria x ananassa	Albritton	CFRA	121	0.001	551435	North Carolina	United States
Fragaria vesca f. semperflorens	Alexandria	CFRA	478	0.001	551826		United States
Fragaria x ananassa	Aliso	CFRA	150	0.001	551657	California	United States
Fragaria x ananassa	Allstar	CFRA	23	0.002	551406	Maryland	United States
Fragaria x ananassa	Ambrosia Late	CFRA	30	0.001	551418	Wisconsin	United States
Fragaria x ananassa	Annapolis	CFRA	964	0.001	552257	Nova Scotia	Canada
Fragaria x vescana	Annelie	CFRA	414	0.001	551769	Bavaria	Germany
Fragaria x ananassa	Apollo	CFRA	127	0.001	551439	North Carolina	United States
Fragaria x ananassa	Appelever	CFRA	91	0.001	551510		France
Fragaria x ananassa	Aprikose	CFRA	1968	0.001	664362	Saxony	Germany
Fragaria x ananassa	Aptos	CFRA	1471	0.001	616761	California	United States
Fragaria x ananassa	ArKing	CFRA	133	0.001	551529	Arkansas	United States
Fragaria x ananassa	Armore	CFRA	170	0.001	551543	Missouri	United States
Fragaria x ananassa	Arnika	CFRA	1782	0.001	617012	Maryland	United States
Fragaria x ananassa	Atlas	CFRA	161	0.001	551535	North Carolina	United States
Fragaria x ananassa	Auchincruive Climax	CFRA	125	0.001	551437	Scotland	United Kingdom
Fragaria chiloensis	Aulon	CFRA	1781	0.001	617011	California	United States

subsp. lucida							
Fragaria x ananassa	Badgerbelle	CFRA	7	0.001	551399	Wisconsin	United States
Fragaria x ananassa	Badgerglo	CFRA	270	0.001	551636	Wisconsin	United States
Fragaria vesca f. semperflorens	Baron Solemacher	CFRA	479	0.001	551507		Germany
Fragaria vesca f. semperflorens	Baron Solemacher light-green mutant	CFRA	983	0.001	552281	New Hampshire	United States
Fragaria vesca f. semperflorens	Baron Solemacher white mutant	CFRA	985	0.001	552283	New Hampshire	United States
Fragaria vesca f. semperflorens	Baron Solemacher yellow mutant	CFRA	984	0.001	552282	New Hampshire	United States
Fragaria x ananassa	Beaver	CFRA	148	0.001	551487	Wisconsin	United States
Fragaria x ananassa	Beaver Belle	CFRA	508	0.001	551839	Alberta	Canada
Fragaria x ananassa	Beaver Early	CFRA	507	0.001	551838	Alberta	Canada
Fragaria x ananassa	Beaver Ruby	CFRA	944	0.001	551837	Alberta	Canada
Fragaria x ananassa	Belrubi	CFRA	160	0.001	551534		France
Fragaria x ananassa	Benizuru	CFRA	159	0.002	551533	Fukuoka	Japan
Fragaria x ananassa	Benton	CFRA	83	0.001	551503	Oregon	United States
Fragaria x ananassa	Berkeley	CFRA	137	0.001	551478	California	United States
Fragaria x ananassa	Big Joe	CFRA	128	0.001	551440	New Jersey	United States
Fragaria x ananassa	Blakemore	CFRA	115	0.002	551421	Maryland	United States
Fragaria x ananassa	Blakemore	CFRA	115	0.003	551421	Maryland	United States
Fragaria x ananassa	Blomidon	CFRA	617	0.001	551914	Nova Scotia	Canada
Fragaria x ananassa	Bolero	CFRA	1668	0.001	616921	England	United Kingdom
Fragaria x ananassa	Bountiful	CFRA	526	0.002	551855	Oregon	United States

Fragaria x ananassa	Bounty	CFRA	122	0.001	551425	Nova Scotia	Canada
Fragaria x ananassa	Brighton	CFRA	73	0.001	551494	California	United States
Fragaria x ananassa	Brighton	CFRA	1472	0.001	616762	California	United States
Fragaria x ananassa	British Sovereign	CFRA	449	0.001	551802	British Columbia	Canada
Fragaria x ananassa	CA 37.20-45 Cruz parent	CFRA	306	0.002	551670	California	United States
Fragaria x ananassa	CA 42.8-16 Tioga parent	CFRA	309	0.002	551673	California	United States
Fragaria x ananassa	CA 51S1-1 Sequoia parent	CFRA	310	0.002	551674	California	United States
Fragaria x ananassa	CA 55.23-1 subtropical (ananassa x chil)	CFRA	311	0.001	551682	California	United States
Fragaria x ananassa	CA 59.39-1 Rockhill 2nd BC	CFRA	313	0.001	551675	California	United States
Fragaria x ananassa	CA 61S16-6 verticillium res.	CFRA	314	0.002	551676	California	United States
Fragaria x ananassa	CA 61S18-30 verticillium res.	CFRA	316	0.001	551678	California	United States
Fragaria x ananassa	CA 64.28-18	CFRA	320	0.001	551716	California	United States
Fragaria x ananassa	CA 64.28-18 8x	CFRA	321	0.001	551717	California	United States
Fragaria x ananassa	CA 65.65-601 Brighton par.	CFRA	322	0.003	551718	California	United States
Fragaria hybr.	CA 67.201-4 (8 x not 14 x)	CFRA	323	0.002	551687	California	United States
Fragaria x ananassa	CA 69.19-12 day neutral	CFRA	326	0.001	551689	California	United States
Fragaria x ananassa	CA 69.72-101 day neutral	CFRA	327	0.001	551690	California	United States
Fragaria x ananassa	CA 70.27-103 day neutral	CFRA	331	0.001	551692	California	United States
Fragaria x ananassa	CA 70.3-117 day neutral	CFRA	328	0.001	551719	California	United States
Fragaria x ananassa	CA 70.3-121 day neutral	CFRA	329	0.001	551720	California	United States

Fragaria x ananassa	CA 70.8-101 day neutral	CFRA	330	0.001	551691	California	United States
Fragaria x ananassa	CA 71.98-605 Parker parent	CFRA	332	0.001	551679	California	United States
Fragaria x ananassa	CA 77.56-101	CFRA	335	0.001	551693	California	United States
Fragaria x ananassa	CA 77.84-103	CFRA	336	0.004	551694	California	United States
Fragaria x ananassa	Califour	CFRA	570	0.001	551903	California	United States
Fragaria x ananassa	Calypso	CFRA	1671	0.001	616923	England	United Kingdom
Fragaria x ananassa	Cambridge Favorite	CFRA	246	0.002	616500	England	United Kingdom
Fragaria x ananassa	Cambridge Late Pine	CFRA	516	0.002	551847	England	United Kingdom
Fragaria x ananassa	Cambridge Rearguard	CFRA	416	0.001	551771	England	United Kingdom
Fragaria x ananassa	Campbell	CFRA	383	0.003	551680	California	United States
Fragaria moschata	Capron	CFRA	117	0.001	551528		France
Fragaria x ananassa	Cardinal	CFRA	166	0.001	551540	Arkansas	United States
Fragaria x ananassa	Catskill	CFRA	3	0.001	551395	New York	United States
Fragaria x ananassa	Cavendish	CFRA	1169	0.001	616560	Nova Scotia	Canada
Fragaria x ananassa	Cesena	CFRA	394	0.001	551754		Italy
Fragaria x ananassa	Chandler	CFRA	2048	0.001	660777	California	United States
Fragaria x ananassa	Cheam	CFRA	90	0.001	551509	British Columbia	Canada
Fragaria x ananassa	Clare	CFRA	1201	0.001	616584	Iowa	United States
Fragaria x ananassa	Clark	CFRA	631	0.001	551960	Oregon	United States
Fragaria x ananassa	Clonderg	CFRA	415	0.001	551770		Ireland
Fragaria x ananassa	Columbia	CFRA	403	0.001	551760	Washington	United States
Fragaria x ananassa	Comet	CFRA	11	0.001	551402	Arkansas	United States
Fragaria x ananassa	Conrad	CFRA	111	0.001	551432		Unknown
Fragaria x ananassa	Cornwallis	CFRA	965	0.001	552258	Nova Scotia	Canada

Fragaria x ananassa	Cruz	CFRA	1248	0.001	616606	California	United States
Fragaria x ananassa	Cyclone	CFRA	13	0.001	551412	Iowa	United States
Fragaria x ananassa	Dabreak	CFRA	211	0.001	551584	Louisiana	United States
Fragaria x ananassa	Dana	CFRA	397	0.001	551756		Italy
Fragaria x ananassa	Dania	CFRA	446	0.001	551799		Denmark
Fragaria x ananassa	Darrow	CFRA	144	0.001	551485	Maryland	United States
Fragaria chiloensis f. chiloensis	Darrow 11	CFRA	621	0.001	235995		Chile
Fragaria x ananassa	Deet	CFRA	129	0.001	551441	Michigan	United States
Fragaria x ananassa	Delite	CFRA	212	0.001	551585	Illinois	United States
Fragaria x ananassa	Delmarvel	CFRA	1207	0.001	616589	Maryland	United States
Fragaria x ananassa	Demerland	CFRA	968	0.002	552261		Uncertain
Fragaria x ananassa	Deutsch Evern	CFRA	260	0.001	551626		Germany
Fragaria x ananassa	Direktor Paul Wallbaum	CFRA	124	0.001	551436		Germany
Fragaria x ananassa	Domanil	CFRA	241	0.001	551610		Belgium
Fragaria x ananassa	Don	CFRA	1263	0.001	616616		Italy
Fragaria x ananassa	Donner	CFRA	190	0.001	551565	California	United States
Fragaria x ananassa	Douglas	CFRA	1774	0.001	551492	California	United States
Fragaria x ananassa	Dover	CFRA	623	0.001	551917	Florida	United States
Fragaria x ananassa	Dunlap	CFRA	494	0.001	551828	Illinois	United States
Fragaria x ananassa	Earlibelle	CFRA	444	0.001	551797	North Carolina	United States
Fragaria x ananassa	Earlidawn	CFRA	244	0.001	551613	Maryland	United States
Fragaria x ananassa	Earliglow	CFRA	1	0.001	551394	Maryland	United States
Fragaria x ananassa	EarliMiss	CFRA	534	0.001	551862	Mississippi	United States
Fragaria x ananassa	Early Midway	CFRA	171	0.001	551544	Maryland	United States

Fragaria x ananassa	Eater	CFRA	1878	0.001	651551	Texas	United States
Fragaria x ananassa	Elista	CFRA	255	0.003	551622		Netherlands
Fragaria x ananassa	Elsanta	CFRA	498	0.001	551579		Netherlands
Fragaria x ananassa	Emily	CFRA	1594	0.001	616854	England	United Kingdom
Fragaria x ananassa	Empire	CFRA	194	0.001	551569	New York	United States
Fragaria x ananassa	Ettersburg 121	CFRA	382	0.002	551904	California	United States
Fragaria x ananassa	Everbearing 185	CFRA	624	0.001	551918	Maryland	United States
Fragaria x ananassa	Everbearing 372	CFRA	625	0.001	551919	Maryland	United States
Fragaria x ananassa	Everbearing 401	CFRA	627	0.001	551921	Maryland	United States
Fragaria x ananassa	Everbearing 417	CFRA	628	0.001	551922	Maryland	United States
Fragaria x ananassa	Eversweet	CFRA	2096	0.001	664445	Indiana	United States
Fragaria chiloensis subsp. pacifica	F. chiloensis subsp. pacifica Yaquina A	CFRA	408	0.001	551765	Oregon	United States
Fragaria virginiana	F. virginiana US 4808	CFRA	1806	0.002	637937	Maryland	United States
Fragaria x ananassa	Fairfax	CFRA	138	0.001	551479	Maryland	United States
Fragaria x ananassa	Fairland	CFRA	118	0.001	551423	Maryland	United States
Fragaria x ananassa	Favette	CFRA	966	0.001	552259	Gironde	France
Fragaria x ananassa	Fern	CFRA	1665	0.006	637930	California	United States
Fragaria x ananassa	Firecracker	CFRA	1773	0.001	617006	Oregon	United States
Fragaria x ananassa	Fletcher	CFRA	143	0.001	551484	New York	United States
Fragaria x ananassa	Florida 70-D-34	CFRA	633	0.001	551925	Florida	United States
Fragaria x ananassa	Florida Belle	CFRA	4	0.001	551396	Florida	United States
Fragaria x ananassa	Florida Ninety	CFRA	18	0.001	551403	Florida	United States
Fragaria moschata	Florika x F. moschata	CFRA	1898	0.001	664347	Bavaria	Germany
Fragaria x	Fortune	CFRA	195	0.001	551570	New York	United

ananassa							States
Fragaria x ananassa	Fou Chu	CFRA	271	0.001	551637		Taiwan
Fragaria x ananassa	Francesco	CFRA	398	0.001	551757		Italy
Fragaria x ananassa	Fratina	CFRA	1785	0.001	617015	Maryland	United States
Fragaria x ananassa	Freja	CFRA	262	0.001	551628		Denmark
Fragaria x ananassa	Fresca	CFRA	2091	0.001	664440	Connecticut	United States
Fragaria x ananassa	Fresno	CFRA	1246	0.001	551659	California	United States
Fragaria vesca subsp. vesca	Frost King	CFRA	573	0.001	551898		United States
Fragaria x ananassa	Ft. Laramie	CFRA	134	0.001	551429	Wyoming	United States
Fragaria x ananassa	Fukuba	CFRA	167	0.001	231088		Japan
Fragaria x ananassa	Gaja	CFRA	1786	0.001	617016	Maryland	United States
Fragaria x ananassa	Garnet	CFRA	147	0.001	551486	New York	United States
Fragaria x ananassa	Geneva	CFRA	213	0.001	551586	New York	United States
Fragaria x ananassa	Gigana	CFRA	418	0.001	551773		Germany
Fragaria x ananassa	Gilbert	CFRA	214	0.001	551587	Wisconsin	United States
Fragaria x ananassa	Glooscap	CFRA	206	0.001	551580	Nova Scotia	Canada
Fragaria vesca subsp. vesca	Golden Alpine	CFRA	1185	0.001	616576	California	United States
Fragaria x ananassa	Gorella	CFRA	142	0.001	551483		Netherlands
Fragaria x ananassa	Governor Simcoe	CFRA	1213	0.001	616594	Ontario	Canada
Fragaria x ananassa	Grandee (Hummi Grandee)	CFRA	192	0.001	551567		Germany
Fragaria chiloensis	Green Pastures	CFRA	1834	0.001	637958	Oregon	United States
Fragaria x ananassa	Grenadier	CFRA	236	0.001	551605	Ontario	Canada
Fragaria x ananassa	Guelph S01	CFRA	203	0.001	551577	Ontario	Canada

Fragaria x ananassa	Guelph S02	CFRA	204	0.002	551578	Ontario	Canada
Fragaria x ananassa	Harunoka	CFRA	162	0.001	551536	Fukuoka	Japan
Fragaria vesca f. alba	Hawaii 4 (F7)	CFRA	2095	0.001	664444	Maryland	United States
Fragaria x ananassa	Headliner	CFRA	634	0.001	551652	Louisiana	United States
Fragaria x ananassa	Hecker	CFRA	1775	0.001	551490	California	United States
Fragaria x ananassa	Herzbergs Triumph	CFRA	1969	0.001	664363	Saxony	Germany
Fragaria x ananassa	Himiko	CFRA	465	0.003	551863		Japan
Fragaria x ananassa	Hogyoku	CFRA	1278	0.002	616622		Japan
Fragaria hybr.	Hokowase	CFRA	1776	0.001	617007		Japan
Fragaria x ananassa	Holiday	CFRA	287	0.001	551653	New York	United States
Fragaria x ananassa	Honeoye	CFRA	215	0.001	551588	New York	United States
Fragaria x ananassa	Hood	CFRA	82	0.001	551502	Oregon	United States
Fragaria x ananassa	Howard 17	CFRA	221	0.001	551593	Massachusetts	United States
Fragaria x ananassa	Hsing Yu	CFRA	200	0.001	551872		Taiwan
Fragaria x ananassa	Idil	CFRA	969	0.001	552262		Canada
Fragaria x ananassa	Independence	CFRA	1765	0.001	616998	Oregon	United States
Fragaria x ananassa	Irvine	CFRA	1982	0.001	660762	California	United States
Fragaria x ananassa	Istochnik	CFRA	1787	0.001	617017		Russian Federation
Fragaria x ananassa	Jaune	CFRA	1788	0.001	617018		
Fragaria x ananassa	Jerseybelle	CFRA	15	0.001	551414	New Jersey	United States
Fragaria x ananassa	Jewel	CFRA	636	0.001	551927	New York	United States
Fragaria x ananassa	Jonsok	CFRA	1789	0.001	617019	Maryland	United States
Fragaria x ananassa	Jucunda	CFRA	256	0.002	551623	England	United Kingdom
Fragaria x ananassa	Jurica	CFRA	250	0.002	551618		Germany

Fragaria x ananassa	K1	CFRA	1496	0.001	616778	Alaska	United States
Fragaria x ananassa	Kaiser's Samling	CFRA	17	0.001	270471		Germany
Fragaria x ananassa	Kama	CFRA	1790	0.001	617020		
Fragaria x ananassa	Kaoling	CFRA	163	0.001	551537		Taiwan
Fragaria x ananassa	Kent	CFRA	216	0.001	551589	Nova Scotia	Canada
Fragaria x ananassa	Klondike	CFRA	189	0.001	551564	Louisiana	United States
Fragaria x ananassa	Komsomalka	CFRA	217	0.001	551590		Russian Federation
Fragaria x ananassa	Koralovaya	CFRA	120	0.001	551424		Poland
Fragaria x ananassa	Kurume	CFRA	199	0.001	551574		Japan
Fragaria x ananassa	Kurume 103	CFRA	16	0.001	551415		Japan
Fragaria x ananassa	Lambada	CFRA	1791	0.001	617021		
Fragaria x ananassa	Lateglow	CFRA	497	0.003	551830	Maryland	United States
Fragaria x ananassa	Latestar	CFRA	1373	0.001	616680	Maryland	United States
Fragaria x ananassa	Lavril	CFRA	1792	0.001	617022	Maryland	United States
Fragaria x ananassa	Lester	CFRA	288	0.001	616501	Maryland	United States
Fragaria x ananassa	Liberation D'Orleans	CFRA	64	0.001	551476		France
Fragaria x ananassa	Lihama	CFRA	1793	0.001	617023	Bavaria	Germany
Fragaria x ananassa	Linda	CFRA	1265	0.001	616618		Italy
Fragaria x ananassa	Linn	CFRA	79	0.001	551500	Oregon	United States
Fragaria x ananassa	Litessa	CFRA	248	0.001	551616		Germany
Fragaria x ananassa	Louise	CFRA	201	0.001	551575	Ontario	Canada
Fragaria x ananassa	Lupton	CFRA	405	0.003	551761	New Jersey	United States
Fragaria x ananassa	Lvovskaya Rannaya	CFRA	1794	0.001	617024		Russian Federation
Fragaria x ananassa	Madame Moutot	CFRA	266	0.005	551632		France

Fragaria x ananassa	Mars	CFRA	659	0.001	551950	Iowa	United States
Fragaria x ananassa	Marshall	CFRA	511	0.001	551842	Massachusetts	United States
Fragaria x ananassa	Marshall	CFRA	511	0.002	551842	Massachusetts	United States
Fragaria x ananassa	Marshall (Japan)	CFRA	186	0.001	231090		Japan
Fragaria x ananassa	Marsyalakaya	CFRA	219	0.001	551591		Poland
Fragaria x ananassa	Massey	CFRA	26	0.001	551431	Maryland	United States
Fragaria x ananassa	Matared	CFRA	1498	0.001	616780	Alaska	United States
Fragaria x ananassa	MD-683	CFRA	409	0.002	551766	Maryland	United States
Fragaria x ananassa	MDUS 3022	CFRA	445	0.001	551798	Maryland	United States
Fragaria x ananassa	MDUS 3184	CFRA	637	0.001	551928	Maryland	United States
Fragaria x ananassa	MDUS 3316	CFRA	638	0.001	551929	Maryland	United States
Fragaria x ananassa	MDUS 3816	CFRA	639	0.001	551930	Maryland	United States
Fragaria x ananassa	MDUS 3839	CFRA	640	0.001	551931	Maryland	United States
Fragaria x ananassa	MDUS 4234	CFRA	641	0.001	551932	Maryland	United States
Fragaria x ananassa	MDUS 4258 (has white chimera)	CFRA	642	0.001	551933	Maryland	United States
Fragaria x ananassa	MDUS 4355	CFRA	643	0.001	551934	Maryland	United States
Fragaria x ananassa	MDUS 4587	CFRA	645	0.001	551936	Maryland	United States
Fragaria x ananassa	MDUS 4588	CFRA	646	0.001	551937	Maryland	United States
Fragaria x ananassa	MDUS 4609	CFRA	647	0.001	551938	Maryland	United States
Fragaria x ananassa	MDUS 4645	CFRA	648	0.001	551939	Maryland	United States
Fragaria x ananassa	MDUS 4774	CFRA	649	0.001	551940	Maryland	United States
Fragaria x ananassa	MDUS 4987	CFRA	650	0.001	551941	Maryland	United States
Fragaria x ananassa	MDUS 5012	CFRA	652	0.001	551943	Maryland	United States
Fragaria x ananassa	MDUS 5097	CFRA	653	0.001	551944	Maryland	United States

Fragaria x ananassa	MDUS 5120	CFRA	654	0.001	551945	Maryland	United States
Fragaria x ananassa	MDUS 5130	CFRA	655	0.001	551946	Maryland	United States
Fragaria x ananassa	MDUS 5136	CFRA	656	0.001	551947	Maryland	United States
Fragaria x ananassa	MDUS 5189	CFRA	657	0.001	551948	Maryland	United States
Fragaria x ananassa	MDUS 5368 R19	CFRA	1208	0.001	616590	Maryland	United States
Fragaria x ananassa	MDUS 5406	CFRA	658	0.001	551949	Maryland	United States
Fragaria x ananassa	Melody	CFRA	1593	0.001	616853	England	United Kingdom
Fragaria x ananassa	Merrimack	CFRA	187	0.001	551562	New Hampshire	United States
Fragaria x ananassa	Mesabi	CFRA	1687	0.001	616936	Minnesota	United States
Fragaria x ananassa	Micmac	CFRA	9	0.001	551400	Nova Scotia	Canada
Fragaria x ananassa	Midland	CFRA	158	0.001	551532	Maryland	United States
Fragaria x ananassa	Midway	CFRA	164	0.001	551538	Maryland	United States
Fragaria x ananassa	Mieze Schindler	CFRA	1971	0.001	664365	Saxony	Germany
Fragaria vesca	Mignonette	CFRA	1686	0.001	616935	New Jersey	United States
Fragaria x ananassa	Mimek	CFRA	448	0.001	551801		Denmark
Fragaria x ananassa	Missionary hybrid	CFRA	1613	0.001	616871	Louisiana	United States
Fragaria x ananassa	Miyazaki	CFRA	1284	0.005	616623	Miyazaki	Japan
Fragaria x ananassa	Mohawk	CFRA	1217	0.001	616598	Maryland	United States
Fragaria x ananassa	Molalla	CFRA	406	0.001	551762	Oregon	United States
Fragaria x ananassa	Morioka 17	CFRA	132	0.001	551428		Japan
Fragaria x ananassa	Nagasaki Queen	CFRA	1288	0.001	616625	Nagasaki	Japan
Fragaria x ananassa	Narcissa	CFRA	119	0.001	551434	Maryland	United States
Fragaria x ananassa	NC 3892 MI	CFRA	660	0.001	551951	North Carolina	United States
Fragaria vesca f.	New Giant	CFRA	477	0.001	551825		United States

semperflorens							
Fragaria x ananassa	Nike	CFRA	1266	0.001	616619		Italy
Fragaria vesca f. semperflorens	Norrland	CFRA	1025	0.001	616509		Sweden
Fragaria x ananassa	Northeaster	CFRA	1664	0.003	616918	Maryland	United States
Fragaria x ananassa	Northland	CFRA	220	0.001	551592	Minnesota	United States
Fragaria x ananassa	Northwest	CFRA	78	0.001	551499	Washington	United States
Fragaria x ananassa	NW 90054-37	CFRA	1822	0.001	641196	Oregon	United States
Fragaria hybr.	Nyoho	CFRA	1779	0.001	617010		Japan
Fragaria x ananassa	Nyohou	CFRA	1290	0.003	616626	Tochigi	Japan
Fragaria x ananassa	Oberschliessen	CFRA	265	0.002	551631		Germany
Fragaria x ananassa	Ogallala	CFRA	165	0.001	551539	Wyoming	United States
Fragaria x ananassa	Olympus	CFRA	84	0.001	551504	Washington	United States
Fragaria x ananassa	Orland	CFRA	113	0.001	551420	Maine	United States
Fragaria x ananassa	ORUS 1083-135	CFRA	1210	0.001	616591	Oregon	United States
Fragaria x ananassa	ORUS 1239R-21	CFRA	1821	0.001	651549	Oregon	United States
Fragaria x ananassa	ORUS 1267-236	CFRA	1820	0.001	651548	Oregon	United States
Fragaria x ananassa	ORUS 2427-1	CFRA	2162	0.001	2162	Oregon	United States
Fragaria x ananassa	ORUS 3727 ORUSM 264	CFRA	940	0.001	552235	Oregon	United States
Fragaria x ananassa	ORUS 3727 ORUSM 265	CFRA	941	0.001	552236	Oregon	United States
Fragaria x ananassa	ORUS 4357 ORUSM 202	CFRA	527	0.001	551856	Oregon	United States
Fragaria x ananassa	ORUS 4816 ORUSM 173	CFRA	530	0.001	551858	Oregon	United States
Fragaria x ananassa	Oso Grande	CFRA	2049	0.001	660778	California	United States
Fragaria x ananassa	Ourown	CFRA	139	0.001	551480	Wisconsin	United States
Fragaria x	Ovation	CFRA	1818	0.001	634800	Maryland	United

ananassa							States
Fragaria x ananassa	Ovation	CFRA	1818	0.003	634800	Maryland	United States
Fragaria x ananassa	Ozark Beauty	CFRA	172	0.007	551545	Arkansas	United States
Fragaria x ananassa	Pai Yu	CFRA	112	0.001	551419		Taiwan
Fragaria x ananassa	Pajaro	CFRA	1949	0.001	657857	California	United States
Fragaria x ananassa	Pantagruella	CFRA	267	0.001	551633		Germany
Fragaria x ananassa	Parker	CFRA	1015	0.002	637924	California	United States
Fragaria x ananassa	Pavlovtchanka	CFRA	1599	0.001	616859	Minsk	Belarus
Fragaria x ananassa	Pegasus	CFRA	1670	0.001	616922		
Fragaria x ananassa	Pelican	CFRA	1844	0.001	637960	Maryland	United States
Fragaria x ananassa	Perle de Prague	CFRA	28	0.001	551408		France
Fragaria vesca f. semperflorens	Pineapple Crush	CFRA	473	0.001	551821		United States
Fragaria x ananassa	Pinnacle	CFRA	1833	0.001	637957	Oregon	United States
Fragaria x ananassa	Pioneer	CFRA	442	0.001	551796	Alaska	United States
Fragaria x ananassa	Pocahontas	CFRA	136	0.001	551477	Maryland	United States
Fragaria x ananassa	Podnyaya Zagorya	CFRA	289	0.001	551594		Poland
Fragaria x ananassa	Precosana	CFRA	410	0.001	551627		Germany
Fragaria x ananassa	Prelude	CFRA	152	0.001	551488	North Carolina	United States
Fragaria x ananassa	Primella	CFRA	116	0.001	551422		Netherlands
Fragaria x ananassa	Primetime	CFRA	1374	0.001	616681	Maryland	United States
Fragaria x ananassa	Prisvyata	CFRA	1795	0.001	617025	Maryland	United States
Fragaria moschata	Profumata de Tortina	CFRA	151	0.001	551549		Italy
Fragaria x ananassa	Profusion	CFRA	188	0.001	551563		France
Fragaria x ananassa	Protem	CFRA	509	0.001	551840	Alberta	Canada

Fragaria x ananassa	Quinault	CFRA	515	0.002	551846	Washington	United States
Fragaria x ananassa	Rabunda	CFRA	258	0.001	551624		Netherlands
Fragaria x ananassa	Rainier	CFRA	500	0.001	551505	Washington	United States
Fragaria x ananassa	Rannyaya Plotnaya	CFRA	1206	0.001	616588		Russian Federation
Fragaria x ananassa	Raritan	CFRA	224	0.001	551595	New Jersey	United States
Fragaria x vescana	Rebecka	CFRA	1901	0.001	664348	Kristianstad	Sweden
Fragaria x ananassa	Red Gauntlet	CFRA	155	0.003	551530	Scotland	United Kingdom
Fragaria x ananassa	Red Gauntlet	CFRA	155	0.006	551530	Scotland	United Kingdom
Fragaria x ananassa	Red Giant	CFRA	396	0.001	551755	Minnesota	United States
Fragaria x ananassa	Red Shore (Krasny Bereg)	CFRA	1598	0.001	616858	Minsk	Belarus
Fragaria x ananassa	Redchief	CFRA	114	0.001	551433	Maryland	United States
Fragaria x ananassa	Redcoat	CFRA	225	0.001	551596	Ontario	Canada
Fragaria x ananassa	Redcrest	CFRA	529	0.001	551859	Oregon	United States
Fragaria x ananassa	Redgem	CFRA	978	0.001	552271	Oregon	United States
Fragaria x ananassa	Redglow	CFRA	240	0.001	551609	Maryland	United States
Fragaria x ananassa	Redstar	CFRA	10	0.001	551401	Maryland	United States
Fragaria x ananassa	Regina	CFRA	1783	0.001	617013	Meckenheim	Germany
Fragaria x ananassa	Reikou	CFRA	1292	0.002	616627		Japan
Fragaria vesca f. semperflorens	Rodluvan	CFRA	1024	0.001	616508	Malmohus	Sweden
Fragaria x ananassa	Royal Sovereign	CFRA	247	0.001	551615	England	United Kingdom
Fragaria x ananassa	Rubin	CFRA	178	0.001	551555		Denmark
Fragaria vesca f. semperflorens	Ruegen	CFRA	66	0.001	551508		Germany
Fragaria x ananassa	S1	CFRA	1497	0.001	616779	Alaska	United States

Fragaria hybr.	S-228 (F. vescana x F x ananassa)	CFRA	1899	0.001	657842	Bavaria	Germany
Fragaria x ananassa	Salinas	CFRA	297	0.004	551661	California	United States
Fragaria x ananassa	Sans Rivale	CFRA	400	0.001	551804		France
Fragaria x ananassa	Santana	CFRA	1473	0.001	666601	California	United States
Fragaria x vescana	Sara	CFRA	1028	0.002	637925		Sweden
Fragaria x ananassa	Savio	CFRA	399	0.001	551758		Italy
Fragaria x ananassa	Scarlet	CFRA	226	0.003	551597	England	United Kingdom
Fragaria x ananassa	Scotland	CFRA	1215	0.001	616596	Ontario	Canada
Fragaria x ananassa	Scott	CFRA	22	0.001	551416	Maryland	United States
Fragaria x ananassa	Seascape	CFRA	2050	0.001	660779	California	United States
Fragaria x ananassa	Selekta	CFRA	533	0.002	551873		South Africa
Fragaria x ananassa	Selkirk	CFRA	1211	0.001	616592	Ontario	Canada
Fragaria x ananassa	Selva	CFRA	466	0.001	551814	California	United States
Fragaria x ananassa	Selva	CFRA	466	0.002	551814	California	United States
Fragaria x ananassa	Seneca	CFRA	1168	0.001	616559	New York	United States
Fragaria x ananassa	Senga Sengana	CFRA	257	0.001	264680		Germany
Fragaria x ananassa	Senga Sengana	CFRA	257	0.002	264680		Germany
Fragaria x ananassa	Sentinel	CFRA	153	0.001	551430	Maryland	United States
Fragaria x ananassa	September Sweet	CFRA	1667	0.001	616920	Delaware	United States
Fragaria x ananassa	Sequoia	CFRA	29	0.001	551409	California	United States
Fragaria x ananassa	Settler	CFRA	1212	0.001	616593	Ontario	Canada
Fragaria virginiana subsp. virginiana	Sheldon	CFRA	285	0.002	551651	South Dakota	United States
Fragaria x ananassa	Shortcake	CFRA	1666	0.001	616919	Illinois	United States

Fragaria x ananassa	Shuksan	CFRA	80	0.001	551493	Washington	United States
Fragaria x ananassa	Sierra	CFRA	179	0.001	551664	California	United States
Fragaria x ananassa	Siletz	CFRA	239	0.001	551608	Oregon	United States
Fragaria x ananassa	Sitka	CFRA	1495	0.001	616777	Alaska	United States
Fragaria x ananassa	Sitka D x Radiance	CFRA	62	0.001	551473	Alaska	United States
Fragaria x ananassa	Sitka D x Red Rich	CFRA	60	0.001	551472	Alaska	United States
Fragaria x ananassa	Sitka hybrid	CFRA	441	0.001	551795	Alaska	United States
Fragaria x ananassa	Sivetta	CFRA	185	0.001	551561		Netherlands
Fragaria x ananassa	Skwentna	CFRA	1499	0.001	616781	Alaska	United States
Fragaria vesca f. semperflorens	Snovit	CFRA	1026	0.001	616510		Sweden
Fragaria vesca subsp. vesca	Snow King	CFRA	580	0.001	551908	Michigan	United States
Fragaria x ananassa	Solana	CFRA	413	0.004	551665	California	United States
Fragaria x ananassa	Solprins	CFRA	973	0.001	552266		Norway
Fragaria x ananassa	Sonjana	CFRA	252	0.001	551619		Germany
Fragaria x ananassa	Soquel	CFRA	1474	0.001	666602	California	United States
Fragaria x ananassa	Sparkle	CFRA	183	0.001	551559	New Jersey	United States
Fragaria x ananassa	Sparkle Supreme	CFRA	2097	0.001	664446	Indiana	United States
Fragaria x ananassa	St. Williams	CFRA	1214	0.001	616595	Ontario	Canada
Fragaria x ananassa	Stelemaster	CFRA	245	0.001	551614	Maryland	United States
Fragaria x ananassa	Stoplight	CFRA	154	0.001	551808	Iowa	United States
Fragaria x ananassa	Stoplight seedling	CFRA	235	0.001	551604	Iowa	United States
Fragaria x ananassa	Streamliner	CFRA	543	0.002	551871	Oregon	United States
Fragaria x ananassa	Sumas	CFRA	499	0.001	551831		Canada

Fragaria x ananassa	Sumner	CFRA	19	0.002	551404	North Carolina	United States
Fragaria x ananassa	Sumner	CFRA	19	0.003	551404	North Carolina	United States
Fragaria x ananassa	Sunrise	CFRA	141	0.001	551482	Maryland	United States
Fragaria x ananassa	Superbe remontant Delbard	CFRA	180	0.001	551556		France
Fragaria x ananassa	Surecrop	CFRA	228	0.001	551598	Maryland	United States
Fragaria x ananassa	Susitna	CFRA	1953	0.001	657861	Alaska	United States
Fragaria x ananassa	Suwannee	CFRA	126	0.001	551438	Maryland	United States
Fragaria x ananassa	Sweet Sunrise	CFRA	2118	0.001	664910	Oregon	United States
Fragaria x ananassa	Syuukou	CFRA	1295	0.004	616628		Japan
Fragaria x ananassa	Tabea	CFRA	1900	0.001	657843		Germany
Fragaria x ananassa	Tago	CFRA	229	0.001	551599		Netherlands
Fragaria x ananassa	Tahoe	CFRA	302	0.002	551666	California	United States
Fragaria x ananassa	Taiwan Farmer	CFRA	532	0.001	551861		Taiwan
Fragaria x ananassa	Talkeetna	CFRA	1500	0.001	616782	Alaska	United States
Fragaria x ananassa	Tamella	CFRA	12	0.001	551411		Netherlands
Fragaria x ananassa	Tangi	CFRA	140	0.001	551481	Louisiana	United States
Fragaria x ananassa	Tango	CFRA	1673	0.001	616925	England	United Kingdom
Fragaria x ananassa	Temple	CFRA	182	0.001	551558	Maryland	United States
Fragaria x ananassa	Tenira	CFRA	254	0.001	551621		Netherlands
Fragaria x ananassa	Tennessee Beauty	CFRA	131	0.001	551427	Tennessee	United States
Fragaria x ananassa	Terunoka	CFRA	1296	0.001	616629		Japan
Fragaria x ananassa	Tillamook	CFRA	1819	0.001	651547	Oregon	United States
Fragaria x ananassa	Tillicum	CFRA	501	0.001	551832	Washington	United States
Fragaria x	Tioga	CFRA	149	0.001	551548	California	United

ananassa							States
Fragaria x ananassa	Tioga	CFRA	303	0.002	551667	California	United States
Fragaria x ananassa	Titan	CFRA	6	0.001	551398	North Carolina	United States
Fragaria hybr.	Tochiotome	CFRA	1777	0.001	617008		Japan
Fragaria virginiana subsp. glauca	Toklat	CFRA	1501	0.001	616783	Alaska	United States
Fragaria x ananassa	Tonami	CFRA	1305	0.001	616633		Japan
Fragaria x ananassa	Tonami-zairai-shikinari	CFRA	1303	0.001	616631		Japan
Fragaria x ananassa	Toots	CFRA	977	0.001	552270	Idaho	United States
Fragaria x ananassa	Toro	CFRA	1249	0.001	616607	California	United States
Fragaria x ananassa	Totem	CFRA	81	0.001	551501	British Columbia	Canada
Fragaria x ananassa	To-Wan	CFRA	460	0.001	551810		Taiwan
Fragaria x ananassa	Toyonoka	CFRA	1304	0.001	616632		Japan
Fragaria x ananassa	Tribute	CFRA	662	0.001	551953	Maryland	United States
Fragaria x ananassa	Tristar	CFRA	663	0.001	551954	Maryland	United States
Fragaria x ananassa	Troubadour	CFRA	268	0.001	551634	Scotland	United Kingdom
Fragaria x ananassa	Trumpeter	CFRA	664	0.001	551955	Minnesota	United States
Fragaria x ananassa	Tufts	CFRA	231	0.001	551491	California	United States
Fragaria x ananassa	Tyee	CFRA	232	0.001	551601	British Columbia	Canada
Fragaria vesca subsp. vesca	UC-04	CFRA	75	0.002	551498	California	United States
Fragaria vesca subsp. californica	UC-05	CFRA	95	0.001	551513	California	United States
Fragaria vesca f. bracteata	UC-06	CFRA	96	0.002	551514	California	United States
Fragaria virginiana subsp.	UC-10	CFRA	76	0.002	551496	California	United States

virginiana							
Fragaria virginiana subsp. virginiana	UC-11	CFRA	74	0.003	551495	California	United States
Fragaria virginiana subsp. virginiana	UC-12	CFRA	77	0.001	551497	California	United States
Fragaria x ananassa	US 4375	CFRA	665	0.001	551956	Maryland	United States
Fragaria x ananassa	US 4387	CFRA	666	0.001	551957	Maryland	United States
Fragaria x ananassa	US 4809	CFRA	1807	0.002	637938	Maryland	United States
Fragaria x ananassa	US-292	CFRA	1190	0.001	616578	Mississippi	United States
Fragaria x ananassa	US-438	CFRA	1192	0.001	616580	Mississippi	United States
Fragaria x ananassa	Vale	CFRA	407	0.001	551763	Oregon	United States
Fragaria x ananassa	Vantage	CFRA	237	0.001	551606	Ontario	Canada
Fragaria x ananassa	Veegem	CFRA	971	0.002	552264	Ontario	Canada
Fragaria x ananassa	Veeglow	CFRA	972	0.002	552265	Ontario	Canada
Fragaria x ananassa	Veestar	CFRA	272	0.001	551638	Ontario	Canada
Fragaria x ananassa	Venta	CFRA	1600	0.001	616860		Lithuania
Fragaria x ananassa	Venta	CFRA	1601	0.001	616861		Lithuania
Fragaria x ananassa	Vermilion	CFRA	20	0.001	551405	Illinois	United States
Fragaria x ananassa	Vesper	CFRA	233	0.001	551602	New Jersey	United States
Fragaria x ananassa	Vibrant	CFRA	234	0.001	551603	Ontario	Canada
Fragaria x ananassa	Vystavochnaya	CFRA	1216	0.001	616597		Russian Federation
Fragaria x ananassa	Weisse Anasa	CFRA	123	0.001	270464		Germany
Fragaria x ananassa	White Carolina	CFRA	384	0.002	551681		United States
Fragaria x ananassa	White D	CFRA	1027	0.001	616511		Sweden
Fragaria x	Wiltguard	CFRA	305	0.003	551669	California	United

ananassa							States
Fragaria x ananassa	Yachiyo	CFRA	181	0.001	551557		Japan
Fragaria x ananassa	Yamagata 2	CFRA	1307	0.002	616635		Japan
Fragaria x ananassa	Yamato-shikinari	CFRA	1306	0.003	616634		Japan
Fragaria vesca f. alba	Yellow Wonder	CFRA	480	0.001	551827		United States
Fragaria x ananassa	Yuzhanka	CFRA	1205	0.001	616587		Russian Federation
Fragaria x ananassa	Zefyr	CFRA	447	0.001	551800		Denmark

Appendix Table 4. Species held at the NCGR-Corvallis (August 2013)

1. *Fragaria bucharica* (4 Accessions)
2. *Fragaria cascadensis* (33 Accessions)
3. *Fragaria chiloensis* (20 Accessions)
4. *Fragaria chiloensis* f. *chiloensis* (24 Accessions)
5. *Fragaria chiloensis* f. *patagonica* (290 Accessions)
6. *Fragaria chiloensis* subsp. *lucida* (20 Accessions)
7. *Fragaria chiloensis* subsp. *pacifica* (33 Accessions)
8. *Fragaria chiloensis* subsp. *sandwicensis* (2 Accessions)
9. *Fragaria chinensis* (3 Accessions)
10. *Fragaria corymbosa* (4 Accessions)
11. *Fragaria daltoniana* (1 Accessions)
12. *Fragaria gracilis* (1 Accessions)
13. *Fragaria* hybr. (30 Accessions)
14. *Fragaria iinumae* (25 Accessions)
15. *Fragaria iturupensis* (1 Accessions)
16. *Fragaria mandshurica* (2 Accessions)
17. *Fragaria moschata* (14 Accessions)
18. *Fragaria moupinensis* (1 Accessions)
19. *Fragaria nilgerrensis* (8 Accessions)
20. *Fragaria nipponica* (13 Accessions)
21. *Fragaria nubicola* (1 Accessions)
22. *Fragaria orientalis* (10 Accessions)
23. *Fragaria pentaphylla* (3 Accessions)
24. *Fragaria* spp. (5 Accessions)
25. *Fragaria tibetica* (1 Accessions)
26. *Fragaria vesca* (19 Accessions)
27. *Fragaria vesca* f. *alba* (18 Accessions)
28. *Fragaria vesca* f. *bracteata* (54 Accessions)
29. *Fragaria vesca* f. *semperflorens* (30 Accessions)
30. *Fragaria vesca* subsp. *americana* (14 Accessions)
31. *Fragaria vesca* subsp. *californica* (7 Accessions)
32. *Fragaria vesca* subsp. *vesca* (29 Accessions)
33. *Fragaria virginiana* (248 Accessions)
34. *Fragaria virginiana* subsp. *glauca* (53 Accessions)
35. *Fragaria virginiana* subsp. *grayana* (50 Accessions)
36. *Fragaria virginia*na subsp. *platypetala* (47 Accessions)
37. *Fragaria virginiana* subsp. *virginiana* (59 Accessions)
38. *Fragaria viridis* (21 Accessions)
39. *Fragaria ×ananassa* (582 Accessions)
40. *Fragaria* × *ananassa* nothosubsp. *cuneifolia* (9 Accessions)
41. *Fragaria* × bifera (2 Accessions)
42. *Fragaria* × *bringhurstii* (15 Accessions)
43. *Fragaria* × *vescana* (3 Accessions)