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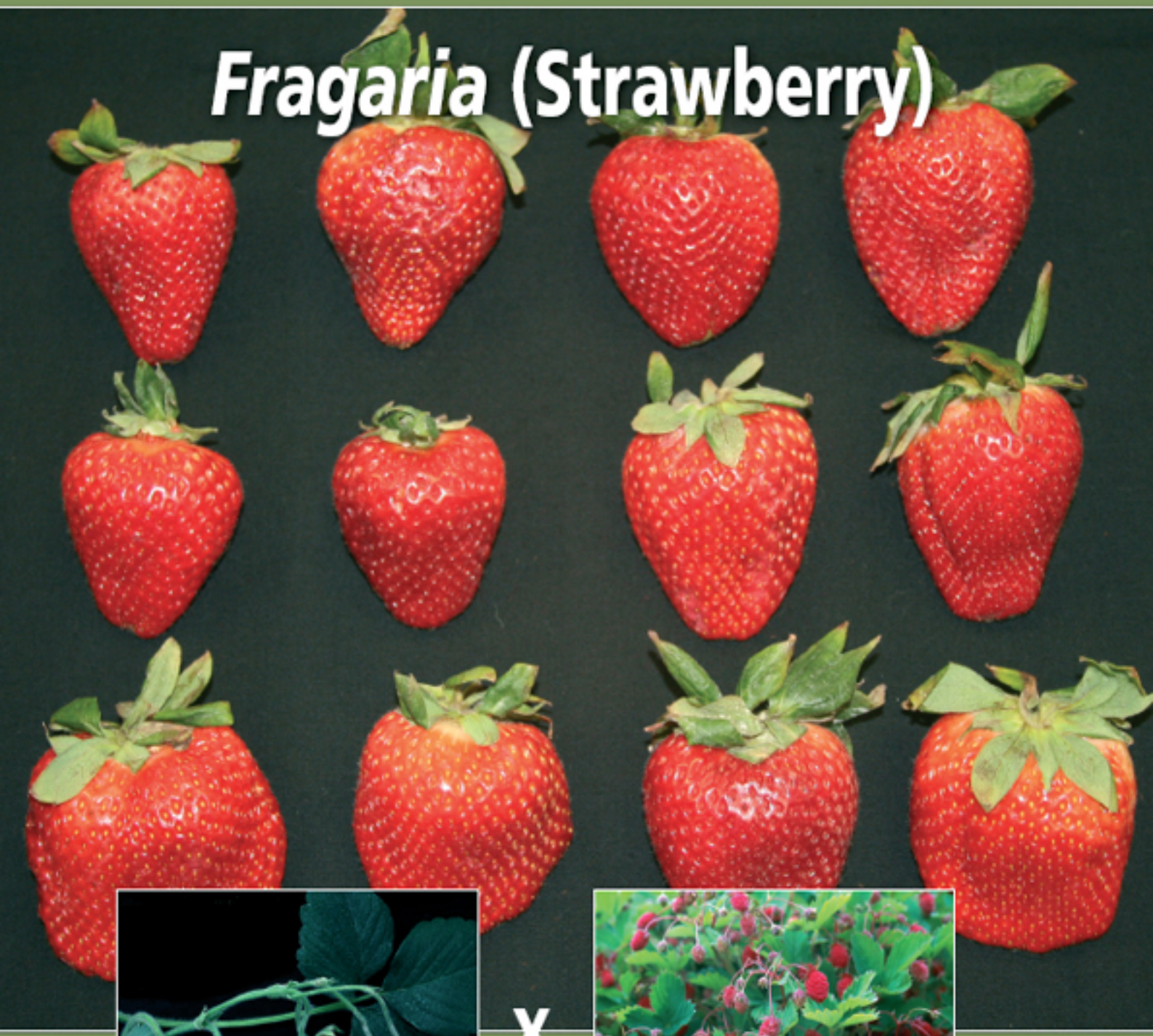
Number 6

Global Conservation Strategy for *Fragaria* (Strawberry)



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ISHS

Global Conservation Strategy for *Fragaria* (Strawberry)

A consultative document prepared in collaboration with partners in the *Fragaria* germplasm, genetics research-and-development community.

Fragaria virginiana, Courtesy of Canadian Clonal Genebank, Harrow, Ontario, Canada

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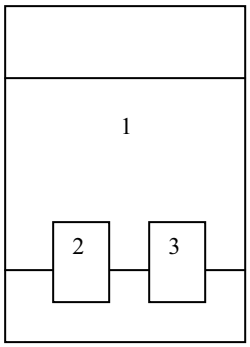
Photograph on the front cover:

1. Cultivated strawberry *Fragaria* ×*ananassa* nothosubsp. *ananassa* Duchesne ex Rozier.
2. White Chilean strawberry, *Fragaria chiloensis* (L.) Mill. subsp. *chiloensis* forma *chiloensis*, the maternal parent of the cultivated strawberry.
3. Virginian strawberry, *Fragaria virginiana* Mill. subsp. *virginiana*, the paternal parent of the cultivated strawberry.



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Great appreciation is given to the strawberry genebank and plant collection managers who provided information for the survey.

DISCLAIMER

This document, developed with the input of a large number of experts, aims to provide a framework for the efficient and effective *ex situ* conservation of globally important collections of strawberry.

The Global Crop Diversity Trust (the Trust) provided support for this initiative and considers this document to be an important framework for guiding the allocation of its resources. However the Trust does not take responsibilities for the relevance, accuracy or completeness of the information in this document and does not commit to funding any of the priorities identified.

This strategy document (dated January 2008) is expected to continue to evolve and be updated as and when circumstances change or new information becomes available.

In case of specific questions and/or comments, please direct them to the strategy coordinator mentioned in the document.

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Executive summary

In 2005, about 3.6 million MT of strawberries, *Fragaria* L., were produced in 75 countries. Strawberry species have a complex background including natural diploid, tetraploid, pentaploid, hexaploid and octoploid 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 350 years. Wild species distributions are limited and landraces may be lost with encroachment of human development. Molecular geneticists are beginning to realize the advantage of working with *Fragaria* and its small-sized genome. Breeders plan to incorporate new sources of wild plant material to expand the restricted cultivated genepool.

Vulnerable wild collections have been identified for future collection and preservation efforts. Internationally, 27 countries and two genebank networks, maintain more than 12,000 accessions in about 57 locations. Roughly half of these represent advanced breeding lines 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. Primary collections at national genebanks consist of living plants, protected in containers in greenhouses or screenhouses, or in the field. Secondary backup collections are maintained *in vitro* under refrigerated temperatures. Long-term backup collections of meristems are placed in cryogenic storage at remote locations to provide decades of security. Species diversity is represented by seed lots stored in -18 °C or backed up in cryogenics. Conservation of vegetatvely propagated material is more complicated and expensive than that of crops that are maintained in the form of seed. The health status of both forms of storage is key for safe global distributions to meet plant quarantine regulations. An international expert committee meeting was held from July 5 to 8, 2006, at the United States Department of Agriculture, Agricultural Research Service, National Clonal Gemplasm Repository, NCGR, Corvallis, Oregon, United States. "Global Conservation Strategy for Strawberry" is based on a strawberry genebank questionnaire completed by 37 responders from 27 countries, about one third of the total countries reporting annual production to FAO (FAO, 2007), provided specific information concerning their collections. From published journals, it is expected that additional major collections are located in China, although no responses were received from collections there. The committee suggested that the development of two country genebanks be supported in China and Chile. A granting system for improved health of strawberries in genebanks should be supported. Limited resources are constraining genebanks from sufficient personnel, secure backup, adequate facilities, and equipment. Training of genebank staff in standard protocols is needed. Coordination of characterization data and web accessible database listing of strawberry genetic resources should also be supported.

1. Introduction: Strategy development process

1.1 Purpose and objectives of the strawberry conservation strategy

Purpose

To contribute to an efficient and effective global conservation system for strawberry genetic resources.

Objectives

- To advise the Global Crop Diversity Trust concerning the status of global strawberry conservation.
- To identify the best approaches to support efficient global conservation efforts.
- To identify collections qualifying for long-term support by the Global Crop Diversity Trust, including their urgent upgrading and capacity building needs.
- To improve global collaboration between the relevant holders of strawberry genetic resources collections.

1.2 Expected outcomes

- An assessment of the collections of strawberry and a widely supported analysis of their importance at the regional and global level.
- A consensus statement of best practices for the management of collections of strawberry.
- The establishment and strengthening of the collaboration between the genebank managers through an advisory group "Global Consortium for Strawberry Conservation".
- A detailed proposal for a global strategy for *ex situ* conservation of strawberry, based on the principles of collaboration and sharing of responsibilities, facilities and tasks, and resulting in rationalization of conservation efforts at regional and global levels, including a proposal for funding priorities.

1.3 Approach

The strategy has been developed in consultation with major strawberry genebank managers. The strategy will be harmonized with relevant regional conservation strategies that are still under development, and will be implemented in consultation with representatives of genebanks, networks, institutions and other stakeholders.

The following steps to develop a draft global strategy have been undertaken:

1. Establishment of contacts with the relevant genebank managers to inform them about the plan for a strategy and to ask for their participation in the process.
2. Inventory of basic information and relevant data on the collections from major stakeholders by means of:
   - a questionnaire, emailed to more than 550 strawberry collection holders and researchers, to establish the current state of strawberry conservation. Through this questionnaire holders of strawberry germplasm have been consulted on the modes of operation regarding their collection;
   - a literature search including through the Internet;
   - personal correspondence with relevant curators.
3. Compiled data obtained prior to, during, and after the Corvallis workshop has been analyzed; the global state of strawberry genetic resources conservation has been assessed at the meeting and in discussions following. Major constraints have been identified. The current level of collaboration between

genebank managers and strawberry researchers has been assessed for safeguarding strawberry genetic resources at the regional and global levels.

4. Organization of the Corvallis workshop on the global strawberry conservation strategy and on best practices for the long-term *ex situ* conservation of strawberry input from curators of global strawberry collections.
5. Identification of collections of major relevance for conservation of strawberry germplasm at the global level.
6. Identification of protocols and recommended best practices for the long-term *ex situ* conservation of strawberry.
7. Evaluation of options for collaboration, sharing of responsibilities and rationalization between strawberry collections at the regional and global level.
8. Establishment of a consortium of strawberry genetic resources curators.
9. Development of a first draft of the global strawberry conservation strategy.
10. Distribution of a first draft of this strategy for comments by the Trust Secretariat and global genebanks.
11. Distribution of a revised draft sent for comments to a selected number of stakeholders.
12. Submission of the final proposal for a Global Strawberry Conservation Strategy to the Trust, including a proposal for funding prioritized activities.

1.4 Focal coordinator for the strategy development process

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1.5 Experts consulted in the development of the strategy

Eighteen Curators and Researchers of globally relevant strawberry collections were invited to participate in the "Expert Committee Meeting on Global Strawberry Genetic Resources" organized from July 5 to 8, 2006, at USDA ARS NCGR, Corvallis, hereafter referred to as Corvallis workshop (Fig. 1). The program for the Corvallis workshop is provided (Annex 1) as is the list of participants (Annex 2).

Fig. 1. Participants in the Expert Committee for development of a global strategy for strawberry genetic resource conservation.
Back (L-R) J. Retamales, J. Postman, Y. Tzanetakis, C. Finn, M. Luffman, T. Davis, M. Höfer, E. Uchendu, K. Folta, B. Reed, N. Bassil, J. Hancock, C. Davidson. Kneeling Front (L-R) K. Hummer, T. Sjulin, P. Roudellac, S. Wada.

1.6 Contributors to the strategy development process

Protocols for strawberry genebank maintenance were discussed at the expert committee meeting (Fig. 2). The protocols for strawberry *in vitro* culture (Annex 3) and pathogen indexing procedures are provided (Annex 4). A questionnaire (Annex 5) was distributed to global genebank managers concerning the status of strawberry genetic resource conservation at their facilities. The responses to the strawberry genetic resource questionnaire are provided (Annex 6). In addition, other genebanks known from the literature or publication are provided (Annex 7).

Fig. 2. Video teleconference between Rome, Italy, and Corvallis, Oregon.

2. Background

2.1 Origin and taxonomy

Strawberry is a very high value per ha crop for which 75 countries report significant production to FAO annually. The strawberry plant is very amenable to many production schemes and can be grown under many climatic zones. This crop has been designated in Annex 1 of the International Treaty on plant genetic resources. This warrants substantial efforts for improvement of this nutritious crop, and for sharing, using, and conserving strawberry genetic resources.

Strawberries, genus *Fragaria* L., are the most economically important soft fruit worldwide. This genus is a member of the Rosaceae, sub-Family Potentilloideae (formerly classified in Rosideae), has *Duchesnea* and *Potentilla* as close relatives. While Mabberly (2002) proposed reuniting, i.e., submerging, *Fragaria* under *Potentilla*, further research (Eriksson et al., 2003) has suggested that Mabberly was premature in this judgment, and genus status has been retained.

The common dessert strawberry, *Fragaria* ×*ananassa* Duchesne ex Rozier nothosubsp. *ananassa*, is a regular part of the diet of millions of people and is cultivated in the arable regions of the globe from the arctic to the tropics. More than 75 countries have significantly reportable amounts of strawberry production (FAO, 2007). Annual world production of strawberries has more than doubled in the last 20 years to over 3.6 million metric tons (Fig. 3). Most of the production occurs in the northern hemisphere (98%), though no genetic or climatic barriers prevent expansion to the south.

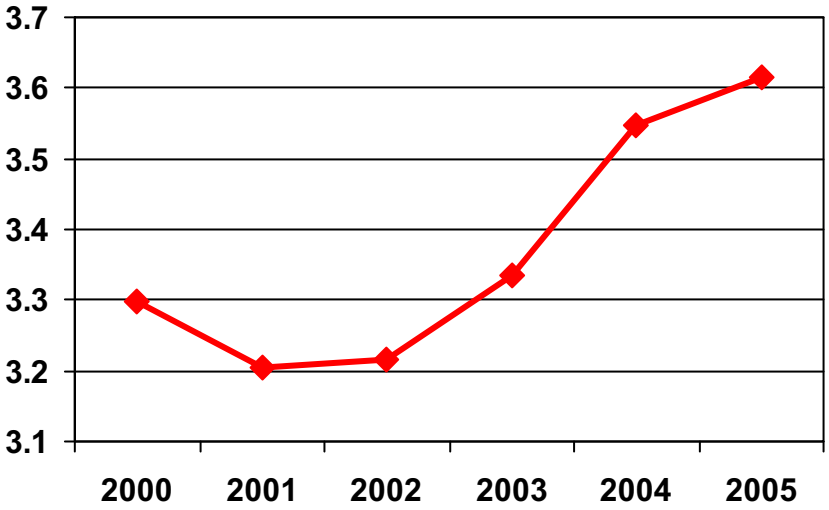


Fig. 3. World strawberry production (FAO, 2007). MT per year.

Fragaria includes 20 species (Table 1) distributed in the north temperate and holarctic zones (Staudt, 1989; 1999). An accurate synonymy and phylogeny of the strawberry species is developing. European and American species of *Fragaria* have been rigorously defined by Staudt (1959, 1999a), who, with colleagues, is proceeding to examine Asian species (Staudt, 1999b; 2001; 2003; 2005). Chinese species are under study (Dai et al., 2007; Lei et al., 2005) but require further collection and examination in light of global taxonomy. The distribution of specific ploidy levels within certain continents reflects the history and evolution of these species (Staudt, 1999a).

Table 1. World strawberry (*Fragaria* L.) species. Hummer and Hancock (2008).

Species	**Ploidy**	**Native location**
F. vesca L.	2*x*	Europe, Asia east of the Urals, North America
F. viridis Weston		Europe and Asia
F. nilgerrensis Schlect. ex J. Gay		Southeastern Asia
F. ×*bifera* Duchesne		Europe
F. bucharica Losinsk.		Himalayas
F. daltoniana J. Gay		Himalayas
F. nubicola (Hook. f.) Lindl. ex Lacaita		Himalayas
F. iinumae Makino		Japan
F. mandshurica Staudt		North China
F. nipponica Makino		Japan
F. gracilis A. Losinsk.		North China
F. pentaphylla Lozinsk.		North China
F. tibetica Staudt & Dickore	4*x*	China
F. orientalis Losinsk.		Russian Far East / China
Syn. = *F. corymbosa* Losinsk.		
F. moupinensis (French.) Cardot		North China

F. ×*bringhurstii* Staudt	5*x*	California
F. moschata Weston	6*x*	Euro-Siberia
F. chiloensis (L.) Miller	8*x*	Western N. America, Hawaii and Chile
F. virginiana Miller		North America
F. iturupensis Staudt		Iturup Island, Kurile Islands
F. ×*ananassa* Duch. ex Rozier nothosubsp. *ananassa*		Bred and cultivated worldwide; cultivar of commerce
F. ×*ananassa* nothosubsp. *cuniefolia* (Nutt. ex Howell) Staudt		California

The primary genepool for the commercial strawberry breeding includes the hybrid octoploid strawberry *F.* ×*ananassa*. Breeders at private companies focus on improvement of elite hybrid cultivars for specific purposes such as yield, season extension, shipability, flavor, insect and pest resistance. The cultivated strawberry gene pool has been restricted (Sjulin and Dale, 1987) but some public breeders have begun incorporating diverse wild plant material from parental octoploid species, *F. chiloensis* and *F. virginiana.*

2.2 History of cultivation

"Fraga" is the Latin word for the strawberry. Linnaeus chose this as a derivative for the genus name. Roman poets Virgil and Ovid wrote of "*fraga"* in their poetry. Virgil (70 to 19 BCE), wrote "*humi nascentia fraga*" [child of the earth] in his third *Eclogue*. Virgil confirms that strawberries were not cultivated during his time when he writes only a warning to children picking wild strawberries to beware of serpents lurking in the grass. Ovid wrote of the "*arbuteos fructus mon-tanaque fraga*" [(They gathered) Arbutus berries and mountain strawberries] in his *Metamorphoses*, book I, v. 104, as furnishing a food of the golden age and again in the 13th book, "*mollia fraga*." Pliny separates the, "*terrestribus fragis*," [ground strawberry] from the arbutus tree in his lib. xv, c. 28. Cato, a Roman Senator (234-149 BCE) mentioned the medicinal uses of strawberries.

The Greeks, Theophrastus, Hippocrates, Dioscorides and Galen, however, did not mention strawberries; nor did other Latin writers on agriculture, Varro, Columella or Palladius. The strawberry is cited in Apuleius Platonicus for its medicinal value (Hedrick, 1919). Strawberries are not mentioned in the Bible, nor do they appear in any Egyptian or Greek art. This could be because of the northerly distribution of the species.

In the 12th century an abbess named Saint Hildegard von Binger declared strawberries unfit for consumption because they grew along the ground where snakes and toads most likely crawled upon them. Her words had such an effect on the local political figures that they, too, made similar declarations, discouraging the population from eating the berries. Among Europeans, this belief held for several years. In the mid 18th century, Charles Linnaeus, the Swedish botanist, put this superstition to rest by switching to a diet consisting only of strawberries to prove them edible (Darrow, 1966).

2.2.1 Old World

Fragaria vesca, the alpine strawberry or fraise de bois, was the first strawberry domesticated in the old world. The ancient Romans and Greeks originally cultivated it in gardens, and by the 1300's, this plant was being grown across Europe (Darrow,

1966). *F. vesca* had its widest popularity in the 1500's and 1600's in Europe before the introduction of strawberry species from the New World.

The musk-flavored *F. moschata* (hautbois or hautboy) was also planted in gardens by the late 15th century, along with the green strawberry, *F. viridis*. *F. viridis* was used solely as an ornamental all across Europe, while *F. moschata* was utilized for its fruit by the English, Germans and Russians. The first strawberry cultivar was a selection of F. moschata called Le Chapiron (1576). This name changed over time to 'Chapiton' and later 'Capiton.' By the later 1600's the name had changed to 'Capron' (Reich, 2004).

2.2.2 New World

Fragaria vesca dominated strawberry cultivation in Europe, until *F. virginiana* from eastern Canada and Virginia began to replace it in the 1600's. Jacques Cartier, who discovered the St. Lawrence River in 1523, was most likely the first to bring *F. virginiana* to the Old World. Cartier mentioned strawberries numerous times in his diary (Hancock, 1999; Wilhelm and Sagen, 1974). The clones that arrived in Europe were wild because the aboriginal peoples of North America did not cultivate strawberries.

A Chilean clone of *F. chiloensis* was brought into Europe in the early 1700's by a French spy, Captain Amédée Frézier (Darrow, 1966; Wilhelm and Sagen, 1974). This strawberry had been domesticated in Chile for about 1,000 years by the indigenous Mapuche, and was spread widely by the Spanish during their colonization period (Hancock, 1999).

2.2.3 American introductions to Europe

After arriving in Europe the Chilean strawberry did not bear fruit for several years and early reports on it were negative. The plants were barren because Frézier had brought back pistillate plants and the need for cross pollination was not initially recognized (Hancock, 1999). The young French Botanist Antoine Nicholas Duschesne discovered that the "Chili" would produce fruit when pollinized by *F. moschata* or *F. virginiana,* two other higher ploidy plants. The "Chili" did not cross with the diploid *F. vesca*. The Chilean strawberry reached its highest acclaim in Brittany, and by the mid-1800's, probably more *F. chiloensis* was cultivated in France than in its native country.

Unusual seedlings with unique combinations of fruit and morphological characteristics began to appear in the gardens of Brittany after *F. chiloensis* was brought to France. While the origin of these seedlings was initially mysterious, Duchesne determined in 1766 that they were hybrids of *F. chiloensis* x *F. virginiana* and he named them *Fragaria* ×*ananassa* to recognize the perfume of the fruit as smelling like pineapple (*Ananas*). The first hybrids of the 'Pineapple' or 'Pine' strawberry may have been selected early in the commercial fields of Brittany, and in botanical gardens across Europe.

The dessert strawberry, *F.* ×*ananassa*, dominates strawberry cultivation and is grown in the arable regions of the world. *F. vesca* is generally restricted to home gardens or local markets where the small, aromatic fruit are considered a delicacy; most of the cultivars grown are everbearers. *F. chiloensis* is currently grown to a small extent in Chile, but has been largely replaced by *F.* ×*ananassa*. Neither *F. viridis* nor *F. moschata* is of significant economic production importance.

2.3 Primary gene pool: cultivated octoploid strawberries

The most economically important strawberry, *F.* ×*ananassa* nothosubsp. *ananassa,* is an octoploid with a sporophytic number of 2*n* = 8*x* = 56 chromosomes. It is an accidental hybrid of two octoploids and arose in the mid-1700's when plants of large white fruited *F. chiloensis* subsp*. chiloensis* f. *chiloensis* imported from Concepción, Chile, were planted in the Royal Botanical Garden of France near smaller red fruited *F. virginiana* subsp. *virginiana* imported from eastern North America. The *F. virginiana* provided the pollen source.

Three hypothetical genome formulae have been suggested for the wild and cultivated octoploids but Bringhurst's proposed AAA'A'BBB'B' (Bringhurst et al., 1990) remains most popular. Bringhurst et al. (1990) stated that octoploids are completely diploidized with strict disomic inheritance. *F. vesca* is likely to be the A genome donor; *F. iinumae*, the B genome donor (Davis et al., 2006). Hybrids of *F. iinumae* that had been chromosome doubled and *F.* ×*ananassa* were highly fertile. Studies of the AdH gene also confirm that ancestors of *F. iinumae* could be linked to the "B" genome (Davis et al., 2006). *F. viridis* may also be part of the background of octoploid strawberries. Like *F. vesca*, its chromosomes pair regularly with those of *F. chiloensis*, *F. virginiana* and *F.* ×*ananassa*. *F. viridis* could represent the A' genome. Davis and Yu (1997) demonstrated that *F. nubicola* or *F. pentaphylla* could also be represented in the A' group because each are interfertile with *F. viridis*. The chromosomes of these species share high levels of homology. Lerceteau-Kohler (2003), used AFLPs and determined that most but not all inheritance is disomic.

The incorporation of traits from a number of lower ploid species has been accomplished through pollinations with native unreduced gametes or by artificially doubling chromosome numbers. The utility of this approach has been shown for a wide range of species in *Fragaria* and in the related genus *Potentilla* (Hancock, 1999). Particular success in incorporating lower ploidies into the background of *F.* ×*ananassa* has come through combining lower ploidy species and then doubling to the octoploid level (Bors and Sullivan, 1998).

2.4 Diploid species

Diploid strawberries can be distinguished by their plant habit, foliage, inflorescence structure, flowers and fruit. *Fragaria* has one of the smallest genomes of vascular plants, though it is somewhat larger than that of *Arabidopsis thaliana*. The *F. vesca* genome size was estimated at 197 Mb (Akiyama et al., 2001) but is probably more correctly represented at 200 Mb (Bennett et al., 2003) or 206 Mb (Davis et al., 2007).

Although ten diploid (2*n* = 2*x* =14) species are native to Eurasia (Table 1), only *F. vesca* is indigenous in northern Eurasia and North America. It is also the only diploid species of North America. Along with other factors, the broader distribution of *F. vesca* suggests that it originated during the Cretaceous (Staudt, 1989). Its ancestor may be basal for the genus.

Although Darrow (1966) and subsequent authors (Hancock, 1999) describe *F. vesca* as native circumpolar boreal, and their distribution maps show *F. vesca* throughout Northern Europe, Asia and North America, this diploid species is not native east of the Urals to Kamchatka (Hultén, 1927-1930), Hokkaido, Japan (Makino, 1979), western Alaska (Hulten, 1968) or Hawaii (Degener, 1975). This species has been recently introduced, i.e., since the time of European explorers, into these regions. *F. vesca* could have been a member of the Arcto-Tertiary Flora. The diploid *F. vesca* is ancient and it's circumboreal distribution may point to an origin as early as Cretaceous time (Staudt, 1984).

While diploid strawberries have some barriers to interfertility, they can be crossed, and meiosis is regular even where interspecific hybrids are sterile (Hancock, 1999). At least three overlapping interfertile groups of diploid species have been suggested (Bors and Sullivan, 1998): 1) *F. vesca, F. viridis, F. nubicola* and *F. pentaphylla,* 2) *F*. *vesca*, *F. nilgerrensis*, *F. daltoniana* and *F. pentaphylla,* 3) *F. pentaphylla, F. gracilis* and *F. nipponica. Fragaria iinumae* may belong in group 3, as no fertile seeds have been recovered when it was crossed with either *F. vesca*, *F. viridis* or *F. nubicola*, but it has not been sufficiently artificially crossed with other species to accurately classify it. *Fragaria iinumae* does, however, have a glaucous leaf trait that is unique among the diploids, and its chloroplast RFLPs clusters it with *F. nilgerrensis* in a group that is isolated from the rest (Harrison et al., 1997).

2.5 Secondary gene pool: higher ploidy species

Polyploidy in *Fragaria* probably arose through unification of 2*n* gametes. Unreduced gametes are relatively common (Hancock, 1999). Bringhurst and Senanayake (1966) found frequencies of giant pollen grains to be about 1% of the total. Over 10% of the natural hybrids generated of these two species resulted from unreduced gametes. Staudt (1989) observed restitution in microsporogenesis of a F_1 hybrid of *F. virginiana* x *F. chiloensis*.

From the biogeography of the genus, the pattern of occurrence of the polyploids, and the distribution of specific characteristics, Staudt (1999) speculated on *Fragaria* origin and evolution. He suggested that East Asia is a center of origin for diploid strawberries. The tetraploid species (2*n* = 4*x* = 28) are also East Asian natives.

The tetraploids may have spread to the periphery of diploid *Fragaria*'s ranges. *Fragaria orientalis* is probably an autopolyploid of *F. mandschurica* (Staudt, 1959; 2003). The tetraploid *F. corymbosa* Los. has been submerged under *F. orientalis* (GRIN, 2007). *F. nilgerrensis* may be the diploid progenitor of the tetraploid *F. moupinensis* (Darrow, 1966). *Fragaria tibetica* seems to be a tetraploid descendent of *F. pentaphylla*. Heteroecy occurs in strawberries in association with doubling of the chromosome number. Diploid *Fragaria* species are not dioecious, though tetraploids (Staudt, 2001), and octoploids are. Tetraploid *Fragaria* species are interfertile (Hancock, 1999).

Wild, naturally occurring pentaploid (2*n* = 5*x* = 35) strawberry species have been observed in California (*F.* ×*bringhurstii* Staudt) and Jilin, China (Lei et al., 2005). These strawberries produce no fertile offspring.

The hexaploid (2*n* = 6*x* = 42), *F. moschata*, is solely European. The musk strawberry, as it is commonly known, is a dioecious, tall vigorous plant that produces few runners. Leaves are large, dark green, rugose, rhombic, prominently veined and pubescent. The flowers are large and the inflorescence is superior to the foliage but droops with ripe berries. The fruit is purplish red, soft, irregularly globose and has a strong flavor. The calyx reflexes. Red and white fruited forms are cultivated (Hancock, 1999).

Native octoploid strawberries are found primarily in North and South America, however, a small distribution of *F. iturupensis* occurs on Iturup, one of the Kurile Islands (Staudt, 1989). This pattern of distribution could be explained if the first hypothetical octoploid arose in East Asia and migrated via an Alaskan-Siberian land bridge to North America.

After arriving in Northwestern America, the hypothetical octoploid may have differentiated into two ecologically distinct groups such as are present today (Staudt, 1999). *Fragaria chiloensis* and *F. virginiana* may be extreme forms of one species that separated during the Pleistocene, and subsequently evolved differential adaptations. One group, *F. chiloensis*, became adapted to coastal habitat; the second, *F. virginiana*, to montane continental conditions. While spreading along the coast, *F. chiloensis* developed the typical shiny, coriaceous, glabrous leaves of the species that we know today. The dispersal of *F. chiloensis* to Hawaii and Chile may have occurred via bird migrations from North America (Hancock, 1999). Staudt (1999) proposed that an ancient *F. vesca* and a hypothetical octoploid *Fragaria* ancestor could have been members of the Arcto-Tertiary flora present from Alaska to Greenland and Siberia that occupied temperate upland areas at middle latitudes in North America during the Eocene. Arcto-Tertiary flora invaded lowlands as temperatures decreased in the Miocene. Towards the end of the Miocene, many species were developed that are closely related to those of the present day (Wolfe, 1969; Ritchie, 1984).

Strawberries are reported on multiple islands surrounding Hokkaido and in the greater and lesser Kuriles. Further exploration and study of strawberries of northern Pacific Islands is needed to determine where other higher ploidy strawberry colonies exist and what their phylogenetic role may have been.

2.6 Intergeneric hybrids

Recently *Potentilla palustris* (L.) Scop. was crossed with *Fragaria* x*ananassa* Duchesne ex Rozier to produce inter-generic hybrid plants that resemble a strawberry plant but have pink flowers. These plants have everbearing strawberry like fruit. Hammer and Pistrick (2003) have proposed the name *F.* ×*rosea* (Mabb.) K. Hammer et Pistrik for this artificial hybrid. Cultivars of these hybrids have been named and patented (Ellis, 1989).

3. Conservation protocols

Ideally, foundation clonal genetic resources should be preserved in triplicate for safety duplication: first as plants in the primary working collection of the genebank; second in an alternative form in on-site secondary collections preferably; and third in a separate base collection at a physically remote collaborating institution. Seed collections are somewhat simpler in that a working collection on site and a remote base collection is minimally sufficient.

Standard procedures for strawberry genebank management is complex and must consider clonal and seed germplasm storage in primary collections. Strawberry cultivars or landraces have unique genotypes and must be maintained vegetatively as plant clones. Strawberry species diversity should be represented through seed and pollen storage.

3.1 Field genebank

Growing strawberry plants in a field is the simplest, and most direct method for clonal genotype preservation as a primary collection. Unfortunately this method does not provide healthy, virus or disease free plants for distribution. Guidelines for field collections of plant germplasm were developed by IPGRI, now Bioversity International (Reed et al., 2005). Some countries, e.g., Denmark (Fig. 4), preserve their primary strawberries collection in the field. Tractors and rotovators till between and within rows to separate plants and maintain identity of plots. Plants are propagated from the mother block and replanted on a rotational basis, every 3 years. In locations with cold winters plants are mulched with straw or are dug and maintained in walk-in coolers,

and are replanted in the spring. Plants can be maintained in a matted row plot which provides room for plants to runner, flower and fruit. Field maps, computer printed labels and careful handling of plant materials can be used to avoid mixing accessions.

Fig. 4. Strawberry genebank at the Pometet, Taastrup, Denmark.

3.2 Protected culture

The advantage of some sort of protected culture for the cultivation of strawberry plants in a genebank setting is to have more control over diseases and pests. A complex of aphid-vectored viruses, viroids, and mycoplasmas are present throughout open fields in most cultivated strawberry regions of the world. Field plantings, without aphid exclusion, allow plants to become infected with disease organisms within one growing season. Strawberry plants will not necessarialy die because of this and genetic resources can be conserved in this fashion. At least two disadvantages for field grown strawberries are that characterization-evaluations results may not show the true nature of the genotype; secondly, diseases can be transmitted though runners or crown divisions. Plant material grown in the field cannot be certified to be pathogen negative for country to country distribution.

3.2.1 Containerized production

Some countries, such as Chile (Fig. 5) , Canada, France, Germany (Fig. 6) and the United States preserve their primary strawberry collection in containers. In this type of situation, care must be taken that runners of one genotype do not invade the space of a neighboring genotype. The genebank at Dresden, Germany chooses long troughs for additional space for plant growth (Fig. 6). The troughs are elevated above the ground and weed-prevention mats are placed underneath.

Fig. 5. The strawberry collection at the University of Talca, Chile.

Fig. 6. The strawberry genebank at Dresden, Germany. Strawberry troughs are labeled and plants are fruited during the summer. Drip irrigation is provided.

The United States uses 16 cm deep by 20 cm wide plastic pots (Fig. 7). Tall pots with (Fig. 7) good aeration give healthy growth of strawberry plants. Application of a pumice topdress (collar) to finished and intermediate sized plant material creates a sterile (dry and inorganic) surface that will prevent weed and moss growth (Fig. 7). This also can prevent or reduce fungus gnats. Fertilizer can be placed under the topdressing. Combining a topdress with a stable, bark-free medium creates a growing system that greatly reduces water usage, nutrient leaching, salt build-up, and moisture stress. The abrupt change from fine growing medium to coarse pumice breaks the hydraulic conductivity between these materials and prevents capillary movement of water to the pot surface. The pumice collar is ideal for vigorous or pot bound material that needs frequent water but should not be used on weak or poorly rooted material.

For xeric, high montane material that needs superior drainage or has a prolonged dry dormancy, a pumice collar should be used only after establishment or not at all. Plants should be repropagated every three years to maintain vigorous growth.

Fig. 7. Potted strawberry plant at the USDA ARS Corvallis genebank. The 16 cm deep by 20 cm wide pot is topped with a pumice collar to prevent weed and moss growth and to act as a moisture loss barrier. Computer printed labels are attached to the pots, while hand written backup labels are placed inside.

3.2.2 Enclosed buildings

Clean strawberry plants must be grown under insect-exclusion conditions to remain pathogen negative (Fig. 8). Greenhouse structures of glass, polycarbonate, or

insect-proof screen (mesh size < 200 μ) can provide protection, when combined with integrated pest management techniques. Plants should be monitored for any insect presence. Weeds growing under benches or directly outside houses must be eliminated because they can attract aphids and other pests. Minimal control treatment, such as soaps or oil sprays, should be applied at the first outbreak of infestation with aphids, or white flies. Some countries require that strawberry plants be grown free of white flies (*Bermesia* spp.) for 90 days prior to any shipment of clonal propagules.

Further protocols on maintaining the health of strawberries in genebanks are presented in section 7.5. Foundation plant material (primary nursery stock) needs to be tested periodically to confirm pathogen-negative status for distribution certification.

Fig. 8. Protective screenhouse for the strawberry collection at the Canadian Clonal Genebank, Harrow, Ontario, Canada. Insets show the strawberry collection and Dr. Margie Luffman, Curator.

3.3 Secondary clonal collections

The primary clonal collections of strawberries in genebanks should be maintained as whole plants in field or under protected cultivation. These plants are the foundation material and are key references for the genebank. Confirmed identification for these type-specimens are absolutely needed. On-site or remote location safety duplication can be achieved through a second whole plant collection, or through alternative storage techniques such as *in vitro* culture or cryogenic preservation of meristems. *In vitro* cultures survive between 3 to 5 years in refrigerated storage while meristems in cryogenics can survive for decades.

Fig. 9. Tissue culture storage at the Chilean, German and United States genebanks.

3.3.1 *In vitro* culture

In vitro storage may be in warm or cool conditions or as meristems or pollen in liquid nitrogen. Storage *in vitro* decreases threats from the environment and from pathogens. *Fragaria* is generally easy to culture and cultures can be stored for 9 to 24 months at 4 °C (Reed, 1991; 1992). Some genotypes, especially those species found in extreme environments, differ in media and protocol preferences. The procedures used at the Corvallis genebank (Reed, 2004) are provided in Annex 5.

3.3.2 Cryopreservation

Strawberry meristems can be cryopreserved by any of the more common cryopreservation techniques, such as slow cooling, vitrification or encapsulation dehydration. Meristems were first cryopreserved using slow cooling with good success (Kartha et al., 1980; Reed and Hummer, 1995; Sakai et al., 1978). More recently, vitrification with plant vitrification solution 2 (PVS2) (Niino et al., 2003), encapsulation dehydration (Ramirez et al., 2005), and encapsulation vitrification (Hirai et al., 1998) were developed for strawberry cryopreservation. Preparation for any of the techniques requires contaminant-free cultures that are rapidly multiplying. Pretreatments of cold acclimation or sucrose are generally required for successful cryopreservation. A book of cryopreservation protocols is now available and includes several strawberry protocols (Reed, 2007).

Fig. 10. Cryopreservation dewars at the Dresden, Germany, genebank.

3.4 Seed conservation

Seed maintenance in any facility, depends on storage capacity, collection methods, species diversity, intellectual property, and the clustering of populations. Seeds provide a natural means of genetic resource preservation and provide an easy safe and cost effective preservation method. The complete “passport” documentation including species identification, collection location (with latitude, longitude and elevation) and description, date of collection, seed photographs, and DNA analysis add to the value of the sample.

Regardless of the lot size, seed germplasm is invaluable. The sample size varies with the accession and depends on many factors, such as environment of the collection site, date of collection, phenology of the particular plants. Ideally, collections greater than 2000 original seeds are prefered for long-term storage. This amount allows for multiple distributions, quality control testing, research studies, and a sub-sample to be sent to a remote back-up or base storage location. If small amounts are obtained, regeneration is needed for increased numbers. For most seeds optimal viability is retained at -20 °C. Even seed that has expired with 0% viability can have useful genetic (DNA) significance.

An assessment of *Fragaria* seed viability should be performed at the time of initial entry into the genebank, and at approximately five years intervals thereafter. Longevity depends on: genetics, seed age, seed health and exposure to pathogens, mechanical damage, seed moisture content, and seed storage temperature. Common

methods of evaluating viability include seed germination tests, x-ray tests, tetrazolium staining tests, and excised embryo grow-outs.

The genus *Fragaria* is quite variable regarding germination requirements (species and location dependant, prior storage conditions – time and temperature). Germination is often improved by after-ripening, pre-chilling and adding light. Studies of strawberry germination showed inter-varietal differences in germination with variables of fresh and dry stored seed along with duration of storage and effects of pre-chilling fresh and dry stored seed. Some require little pre-treatment prior to germination whether planting fresh or dry seed. However, pre-chilling improved dry-stored seed emergence which had initially low germination (Adam and Wilson, 1967). Delayed and incomplete germination are often limiting factors in strawberry breeding. Special pre-treatments such as sulfuric acid and sodium hypochlorite scarification and cold temperature stratification can hasten germination and can allow for more rapid and uniform emergence (Bringhurst and Voth, 1957). Germination of seed from different strawberry cultivars was variable (1934). F_1 germination results of different crosses and germination at different temperatures were also evaluated. Handling procedures and seasonal planting times for best germination results were tested (Henry, 1934). Studies of strawberry seed germination show that planting seeds at the surface with sufficient light enhances rapid germination and growth. Germination in the light was significantly better than dark germination (Scott and Draper, 1967). Germination protocols and pre-treatments, durations, light and other requirements for strawberry germination are examined in the AOSA handbook. Problems with dormancy and methods of breaking dormancy are also discussed. Various media and chemicals used on the media were also evaluated (AOSA, 2000). Germination protocols and dormancy breaking methods are discussed in the ISTA manual. Scarification techniques are extensively covered (ISTA, 1998).

Several studies evaluated the storage of strawberry seeds. Harrington (1972) evaluated orthodox seeds (like *Fragaria*) in storage at several temperatures and seed moisture contents over time and effects on seed longevity, germination and vigor. Storage techniques for orthodox seeds (strawberries) were discussed by Justice and Bass (1978). Cold storage at -20 °C was favorable for seed longevity and strawberry storage maximum was about 23 years using dry down and cold-storage methods (Justice and Bass, 1978). Germination tests with strawberry seed of different ages (1-23 years) stored at 4.5 °C were examined by Scott and Draper (1970). All seed lots performed well and had high germination percentage despite different lengths of storage.

Tetrazolium test

The tetrazolium test (TZ) on *Fragaria* provides a quick and accurate evaluation (24 hours) for viability of the seed accession. It is a topical staining test of living tissues within the seed (including the embryo). If the seed is viable and respiring, the embryonic tissues will stain pink to red in color. Even viable dormant seed will stain with this test. [Note: The TZ is a 'destructive' test on the seed. X-raying seeds has been used with some success with viability determination and is 'non-destructive'.]

TZ protocol

A small seed sub-sample (10-50 seeds) is taken from the accession. Seeds are moistened overnight (16 hours) to soften seed and initiate germination enzymatic activity. Seeds are cut longitudinally to expose the embryo. Seeds are placed in a solution of 1.0% 2,3,5 tri-phenyl tetrazolium chloride for 5 hours at either room temperature or in an oven at 35 °C (if under a time constraint to complete the test).

Embryonic staining is evaluated under a dissecting microscope to determine viability. Red color indicates living tissue.

Other viability tests

Excised embryo grow-out and x-ray tests can be used to determine viability although they are not commonly used with *Fragaria*.

Seed processing

Store only dry, clean, uncontaminated seed (free of off-types, weeds, pathogens). Seeds may come as fruit (on or off the plant), as freshly harvested seed (possibly with chaff and contaminants included), or as older seed that was perhaps stored elsewhere.

Seed extraction protocol

If seed enters as fruit, place the fruit in a zip-lock plastic bag along with a few drops of pectinase and a few ml of water, to soften the fruit and pull the pulp away from the seed. Let stand for 1-3 days to soften fruit thoroughly. By the time pectinase is done, the seeds are at the bottom and the slurry of dissolved flesh is in suspension. With dry seed, remove impurities by either hand cleaning or using a series of meshed sieves (removes large chaff and inert matter) or seed blower (removes small chaff and little, immature seed).

Either hand count or machine count, using an automated seed counter, the total number of seeds. After this step, weighing the counted, cleaned seed is optional. This 'amount' data is entered into the inventory database. The seed is now ready for final dry down, packaging, and storage.

Storage conditions

Most orthodox seeds, like *Fragaria*, store well under cold and dry conditions. Storage in freezers at -20 °C is commonly used for *Fragaria* seeds. Cryopreservation in liquid nitrogen is possible for dry seed.

Storage protocol

After seed processing (extracting and cleaning) the seeds are placed in desiccators with silica gel or calcium sulfate and dried for approximately 7 to 14 days. (Seed moisture content will drop to below 10% after the desiccation procedure).

Viability tests – Germination or tetrazolium tests are conducted on a small sub-sample of the seed accession prior to storage. The vital information is stored in an inventory database. Seeds are placed in a small, labeled sample bag and then in a larger foil, plastic-lined seed storage bag (with an identification label) which is then heat sealed.

The foil seed-storage bag is then file stored in a -20 °C freezer. Periodic viability retests are conducted on a seed accession subsample to determine viability changes over time.

Distribution

Seeds are distributed to the public upon request and availablility. Sample bags are retrieved and cut open. Sub-samples of seed are removed from the storage bag. The amount of seed distributed is partly determined by the available amount seed.

The storage bags are immediately resealed and returned to cold storage. The seed distributed are subtracted from the inventory in the database and on the storage bag.

Regeneration

Regeneration of seed can be performed either from seed-to-plant-to-seed, or from plant- to-seed. Seed regeneration occurs with genetic recombination, so the genetic constitution of the next generation of seed will not be identical, but will be dependent on the parent genotypes. Some species of strawberries are out crossing types and do not tend to come true to parental types. Other seedlings, such as those of *Fragaria vesca*, remain close to parental genotypes. The need for regeneration can be triggered by any one of the following conditions:

- Seed amounts are dangerously low (<200).
- Seed viability is low or quickly deteriorating.
- Seed requests and distribution of the accession are exceptionally high (germplasm frequently requested).
- Plants in the field or greenhouse have failed and therefore more seedlings are necessary to produce replacement plants.
- Multiple plant populations exist and there is a need to consolidate and group these clustered populations as a collective accession and reduce plant material.

Regeneration must be conducted in a closed environment to prevent cross-pollination and contamination. Population biology issues regarding the number to plants necessary to embrace the maximum characteristics and ensure genetic diversity and limit the genetic drift of the accession are other important variables to consider.

<u>Regeneration: Seed-to-plant-to-seed</u>

This requires germinating randomly selected seed from the accession as well as establishing and maintaining enough seedlings/plants in the population for genetic diversity.

Take a sub sample of the seed accession (enough seeds to germinate at least 20 seedlings or as many seeds as possible if the accession has a small and limited amount of seed). Germinate the seeds under the same conditions mentioned in the 'germination rules' or use a seedling media to germinate the seeds instead of blue blotters or sand [With *Fragaria*, it is best to initiate germination in mid-winter].

Place seedlings in greenhouse and fertilize well. Just prior to strawberry plants reaching a good size and reproductive maturity (flowering) 15 months later (the following spring) isolate the plants of the same accession in a greenhouse or in outdoor beds or in the field. Isolate using pollen or insect cages, or physical distance from other populations of the same genus.

Allow the plants to 'self pollinate' among its population by either controlled hand pollination methods or emasculation/brush techniques, or by the introduction of pollinating insects (bumble bees, honeybees, or blue bottle flies) to the insect cages.

Collect fruit from the plants when they mature in early to mid summer. Follow procedures for the seed processing of fruit. Dry the seeds for 48 hours. When packaging the newly harvested seed, assign the same accession number as the original seed, label as such and keep in a <u>separate</u> small envelope or packet with the harvest date noted on the label and place into the original seed accession foil storage packet. Update *Fragaria* seed 'amount' information in the database and return sealed storage bag to the -20 °C freezer.

<u>Regeneration: Plant-to-seed</u>

Regeneration from plant to seed eliminates the need to germinate new seedlings and grow sexually mature plants from seed. Already established, vegetative *Fragaria* plants will produce runners in early spring. These daughter runners can be re-

propagated and produce a meager seed crop 4 months later or a healthy seed crop the following year.

In early spring, re-propagate *Fragaria* runners into 10 cm pots. Once runners have rooted, remove the runners from the mother plant and continue to water and fertilize the newly established daughter plants. Follow procedures (outlined above) in regard to transplanting, isolating, pollinating, harvesting, extracting and processing, drying, and packaging the regenerated seed.

3.5 Health of collections

Strawberry clones can be susceptible to many diseases, disorders, and pests (Maas, 1998). Some diseases are ubiquitous throughout the globe but are of concern for healthy plant maintenance within the genebank. Plants grown in enclosed environments need to have adequate air circulation to reduce fungal and bacterial diseases. Field grown plants should be grown with drip irrigation, both for the water savings, and to reduce fungal infections. Overhead irrigation can increase foliar fungal infections.

The discussion below will focus on diseases and pests of quarantine significance. These must be controlled to prevent distribution of the diseases along with the germplasm.

3.5.1 Viruses and virus-like disorders

More than 30 viruses, virus-like disorders and phytoplasmas have been identified to infect strawberries (Martin and Tzanetakis, 2006). Strawberry viruses are listed (Table 3.5.1). Field grown strawberries are commonly infected with multiple viruses or virus-like diseases. Because cultivated strawberries are clonally propagated, viruses can be inadvertently distributed within field-gathered propagation stock. Viruses can also infect *in vitro* cultured plantlets, unless virus elimination procedures are followed, or meristems originate from virus-negative certified foundation plant material.

Fig. 11. Strawberry with phylloide symptoms from phytoplasma.

Table 3.5.1 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.

Martin (2004) has recommended procedures for detection of strawberry viruses. These tests include bioassays on indicator plants, sap and graft inoculation, enzyme linked imunosorbant assay, double-stranded RNA detection and polymerase chain reaction (PCR) (Annex 6).

Plant material should be obtained from sources with the lowest risk of pathogen 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 recepient 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.

3.5.2 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 *Phythophthora fragariae* var. *fragariae* Hickman, runners should be propagated. Diekmann et al. (1994) describes symptoms, host range, geographical distribution, biology and transmission of the disease. Leaf spot (*Alternaria*), Anthracnose (*Colletotrichum*), fusarium wilt, verticillium wilt, phythophthora crown rot (*Phytophthora cactorum* (Lebert & Cohn) Schröt.), bacterial leaf spot (*Xanthomonas)*, and strawberry black root rot are described.

3.5.3 Insect and arthropod pests

Insects and mites are major threats to cultivated strawberry plants. For example, nearly 200 species of insects and mites have been reported to infect strawberry plants in North America (Maas, 1994). 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.

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.

3.6 Genetic identity

Isozymes (allozymes) were early markers that fingerprinted or identified strawberry cultivars. While they could identify many cultivars, some could not be distinguished due to low polymorphism (Arulsekar et al., 1981; Bringhurst et al., 1981; Greco et al., 1993). A second disadvantage of this technique was that it examined proteins, rather than the genes that made the proteins.

Random Amplified Polymorphic DNA (RAPD) markers was the first polymerized chain reaction (PCR)-based method to overcome the limitations of allozymes. In strawberry, RAPDs were successfully used for cultivar identification (Garcia et al., 2002; Harrison et al., 2000) even in closely related cultivars (Hancock et al., 1994; Gidoni et al., 1994). The RAPD technique was accepted in the court of law where unambiguous identification of a strawberry cultivar, 'Marmolada' was required (Kunihisa et al., 2004). RAPD markers were also used to distinguish between North and South American subspecies of *F. chiloensis* (Porebski and Catling, 1998). To increase reproducibility, the RAPD technique was modified to generate sequence characterized amplified regions (SCARS) or cleaved amplified polymorphic sequences (CAPS). Six CAPS markers were reproducible and identified 90% of the strawberry cultivars evaluated (Kunihisa et al., 2003).

Amplified fragment length polymorphism (AFLP) markers are attractive because of the large number of variable genetic markers generated quickly from previously uncharacterized genomes. This technique requires only a small amount of DNA. AFLP

markers have been applied to fingerprinting and assessing genetic diversity of strawberry cultivars (Degani et al., 2001; Lerceteau-Kohler et al., 2003).

Microsatellites or simple sequence repeats (SSRs) have become a preferred tool for cultivar identification due to their codominance, multiallelism, and high rates of polymorphism and reproducibility. In *Fragaria*, microsatellite markers were developed from genomic libraries (Lewers et al., 2005; Monfort et al., 2005; Nourse et al., 2002) from *Fragaria* GenBank sequences (Lewers et al., 2005) and from expressed sequence tags (EST) (Bassil et al., 2006; Folta et al., 2005; Keniry et al., 2006). Most microsatellite markers in strawberry were developed from the diploid *F. vesca* (Cipriani and Testolin, 2004; Hadonou et al., 2004; James et al., 2003; Monfort et al., 2005). *F. vesca* has been suggested as a model species due to its small genome size (164 mbp) (Bennett et al., 2000) and its contribution to the genome of the cultivated species (Senanayake and Bringhurst, 1967). Microsatellite markers were also developed from *F. ×ananassa* (Bassil et al., 2006; Gil-Ariza et al., 2006). A limited number of SSRs were isolated from other *Fragaria* species and they include four from *F. virginiana* (Ashley et al., 2003) and twenty-two from *F. viridis* (Sargent et al., 2003).

A high level of cross-species transferability was reported within *Fragaria* (Ashley et al*.,* 2003; Bassil et al., 2006b; Lewers et al., 2005; Monfort et al., 2006; Sargent et al., 2003). This high cross-species transferability in *Fragaria* increases microsatellite usefulness and allows comparative mapping.

Microsatellites were recently applied to *Fragaria* for cultivar identification (Shimomura and Hirashima, 2006). Four microsatellite markers were developed from a genomic library of a Japanese *F. ×ananassa* cultivar, 'Toyonoka' and were tested for fingerprinting of ten cultivars (Shimomura and Hirashima, 2006). Two of the four primers were able to distinguish between the ten strawberry cultivars tested and the estimated polymorphism was high.

Genetic identity must be monitored within any genebank. Even with careful propagation and avoiding off-types, botanical and horticultural identities of strawberries in the genebank must be periodically checked. Herbarium collections, photographs, and DNA marker analysis can assist in the correct identification of accessions, but expert plant examinations are also needed on a regular basis. Once molecular databases are established, collections can be compared with the standards for that genotype. Incorrect labeling, mixing of propagules, contaminating runner plants and seedling development present the greatest challenges for correct identity assurance in clonal strawberry germplasm management.

Microsatellite markers have become a preferred tool for universal germplasm identification and comparison of genetic profiles across international laboratories. In strawberry, an international group of scientists is collaborating to develop a universal fingerprinting set for cultivar identification in strawberry.

4. Networks

COST Action 863 and GENBERRY (Previously COST Action 836)

Only one regional, inter-country network for genetic resource conservation exists for strawberries: the European Cooperation in the field of Scientific and Technical Research (COST 836) in Europe (Roudeillac and Boxus, 1997; Geibel and Roudeillac, 2000; Geibel, 2002; Baruzzi et al., 2003; Geibel et al., 2004). In 1992 to 1993, 24 institutes from 16 European Countries, including Russia, collaborated to establish an inventory of 900 old and recent strawberry cultivars (Roudeillac and Boxus, 1997). By 1995, 20 partner countries were included (Geibel and Roudeillac, 2000) and in 2004, 1056 unique genotypes and 418 wild species accessions are preserved (Geibel et al., 2004). Counting duplicates between countries, 2819 cultivar

accessions are preserved. A core collection of 106 cultivars has been selected based on historical significance or expression of important traits. These European countries have agreed to common ontology of evaluation traits. They also have an interconnected database on the web.

COST Action 863, the EUROBERRY agreement, has been initiated for continued collaboration beginning in 2004. The main objective of the Action is to improve the quality and production of berries to benefit health of the consumers and to maintain profitable European production using sustainable systems. The new project will benefit from the experiences developed on strawberry during COST Action 836 and will be extended to other berry species that are important in European countries. By using a new interdisciplinary approach the programme will focus on selected topics of major importance for the European berry production system and quality control.

An improvement of the European cooperation regarding the genebank will be reached with the new EU project AGRI GEN RES 036, "European small berries genetic resources," started September 2007. The following objectives are included: rationalization and conservation of *ex situ* collections; definition and selection of primary and secondary descriptors; characterization of the genetic diversity using molecular markers; characterization for health nutritional compounds and for disease resistances; dissemination of the results to the public and elaboration of a European small berries database.

In 2007, 31 countries became members of COST and 52 locations have representatives (http://www.euroberry.it/).

Table 4.1 Strawberry genebank locations and contacts in COST Action 836 (after Geibel et al., 2004).

Location of Genebank	**Curator**	**Cultivars**
Belgium, Gembloux	Hugo Magein	28
Bulgaria, Kostinbrod	Violetta Kondakova	190
Denmark, Taastrup	Torben Toldam-Andersen	171
England, East Malling	David Simpson	171
Finland, Piikkiö	Tarja Hietaranta	50
France, Balandran	Jean Claude Navatel	172
France, Bergerac	Philippe Chartier	101
Germany, (BAZ) Pillnitz	Barbara Dathe	136
Germany, (IPK) Pilnitz	Monika Hofer	312
Germany, Wurzen	Erik Schulte	302
Italy, Forli	Walter Faedi	191
Lithuania, Babtai	Rytis Rugenius	101
Netherlands, Wageningen	Bert Meulenbroek	17
Norway, Stjordal	Jan Davik	121
Poland, Skierniewice	Agnieszka Masny	157
Romania, Cluj	Sebastian Cracea	143
Romania, Pitesti	Mihail Coman	136
Spain, Malaga	José F. Sánchez-Sevilla	246
Sweden, Balsgard	Karin Trajkovski	12
Switzerland, Basel	Martin Frei	56
Total accessions		2819
Total unique cultivars		1056
Number of species		418

Now COST Action 863, the EUROBERRY agreement, is being initiated for continued collaboration beginning in 2007.

The Nordic Genebank, is another distributed genebank with members including Norway, Sweden, Finland, Denmark, Estonia, Latvia, Lithuania and Iceland, have fruit and nut genetic resources preserved but strawberries are not specified. The Nordic Genebank countries participate in the database for the European cooperative program for plant genetic resources (EURISCO).

5. Status of strawberry conservation

Preservation of clonal strawberry germplasm is resource consuming and labor intensive. To maintain the genotype identity, runners from adjacent containers or plots must be prevented from becoming established and flowers and fruit must be removed so that volunteer seedlings do not develop. These tasks must be performed in addition to usual plant cultural activities such as watering, fertilizing, repotting, and pruning. Air circulation is important to prevent foliar fungal diseases. Soil pathogens must be controlled. Pathogen testing must be performed regularly with close monitoring to prevent vectors from entering the area and re-infecting plants.

No international centers or consultative groups have been previously formed to guide the preservation of global strawberry genetic resources. This crop, while being of sufficiently high value per hectare crop to warrant inclusion on Annex 1 of the ITPGR, remains a specialty crop, of lesser official agricultural importance to most governments. Determining a total count of strawberry genebanks is challenging. Bettencourt and Konopka (1989) listed 27 strawberry genebanks in 19 countries. Diekmann et al. (1994) mentioned 14 strawberry genebanks in 11 countries, but this list was not exhaustive.

In our survey we received 37 responses from 27 countries (Annex 6), although, through scientific contacts and published information, the expert committee is aware of additional countries (Annex 7) with national strawberry collections, which have functioned as genebanks. For example, 7 of the COST countries with known actively maintained strawberry genebanks did not respond to our survey.

We hypothesize that recently the trend has been for an increasing number of public research institutions, particularly universities, to either close or greatly reduce the holdings of their strawberry genebanks, or to privatize them. Public funding for small or soft fruit research and breeding has declined radically during the past 20 years. Agricultural administrators face budget challenges. They expect that any “worthy” strawberry breeding program, following the University of California model, will be able to fund its own research through returns from intellectual property of patented cultivars. Australia, Ireland, Scotland, and Sweden have recently closed or reduced the size of their strawberry genebanks due to lack of federal public funding and support.

Public genebanks, university collections and private genebanks responded to our questionnaire. Of the respondent genebanks, 22 institutions were governmental, 7 belonged to universities, and 7 additional were supported through private resources. We estimate that 12,021 accessions exist in the respondent genebanks (Annex 8). Additionally 3,000 accessions, mostly advanced selections or breeders lines and a few heritage or regional cultivars, probably exist in the additional non-responding countries, making the total international strawberry collections to be about 15,000.

Besides these international genebanks, numerous, short term, private, university, and research collections exist for directed strawberry breeding programs. From the literature, the expert committee estimates that about 30 additional countries (besides those mentioned in Annex 7 and 8) commercially produce strawberries and many of these have specific breeders or evaluation collections to support this industry.

We estimate that these private collections double the amount of conserved strawberry accessions in the world. However, the older specimens of these collections tend to be periodically purged and replaced with improved types to forward the breeding programs. These protected programs serve only private interests, do not freely distribute, and are not subject to the International Treaty. These collections do not provide long-term conservation and are completely privately funded. Their interaction with international genebanks is primarily to obtain broader genetic base for their programs. They do not distribute their protected genotypes to the public, and only under agreements to other researchers.

In response to the questionnaire 19 strawberry collections described their collections as long-term interest genebanks (Annex 8, 9) with distribution activities. The main features of these strawberry genebanks are described (Annex 9). Each of the genebanks, except one, described their collections to be of regional or national interest. Heritage strawberries of those countries, or cultivars with qualities applicable to their country's specific needs, were preserved in their banks. The US and the Russian Federation were the only genebanks that specified the objective of maintaining a global collection.

Judging from the survey results, six "major" country genebanks, and one network (COST), each preserve more than 500 accessions in their primary collections. These genebanks are (in order of amount): United States, Canada, Russia, Germany, Spain and Chile (Table 4.1). About 8,000 accessions, or about 66% of the total strawberries conserved in genebanks, are maintained in these 6 largest banks.

Table 5.1 Major (> 500 accessions) strawberry genebanks and cooperatives.

Germplasm Collection	Total number	% Species	% Genotypes	% Backed up
United States, Corvallis, Oregon	1924	60 %	40 %	20%[z]
Canada, Harrow, Ontario	1782	57%	43%	25%
COST 836 (network)	1456	27%	73%	50%
Russian Federation	1210	10 %	90%	24%[y]
Germany	660	45%	55%	some tc
Spain [x]	660	30%	70%	100%
Chile, Talca	546	95%	5%	some tc
Total	8238			

[z] Clones in tissue culture and cryogenics on-site and in Colorado; seed in Colorado.
[y] In breeder collections at Krasnodar, and Murmansk.
[x] From Sanchez-Sevilla et al. 2004.

Profiles for the major genebanks follow.

5.1 United States

The national strawberry genebank (Fig. 8) for the United States resides at the Department of Agriculture, Agricultural Research Service, National Clonal Germplasm Repository, 33447 Peoria Road, Corvallis, Oregon. This facility, established in 1981, has a mission to collect, preserve, distribute, and evaluate global diversity of 30 genera including strawberry genetic resources. The base funding of this facility is federal, appropriated annually through the budget of the Department of Agriculture. Repository scientists apply for additional non-base funds to supplement the evaluation effort. This facility is part of the US National Plant Germplasm System. The genebank has four scientists, including a horticulturist (curator), plant pathologist, plant physiologist and

geneticist. In addition 10 technical and support staff assist in conservation efforts. The primary clonal collection of *Fragaria* is stored as potted plants inside an aphid-proof screenhouse. An on-site secondary collection of about 10% of the primary genotypes is preserved as *in vitro* cultures which can be stored in plastic containers under refrigeration for 3-5 years without re-culturing. The broader species diversity is represented by seedlots stored at -20 °C.

The Corvallis genebank collaborates with the USDA ARS National Center for Genetic Resource Preservation, in Ft. Collins, Colorado, which provides the location for remote secondary (base) storage of strawberry germplasm. At Ft. Collins, genotypes are preserved as *in vitro* cultured plantlets and as cryogenically preserved meristems, and as seed stored at -20 °C. About 10% of the strawberry genotypes are backed up in tissue culture and about 10% of the seed accessions are secured in Ft. Collins. The Corvallis genebank probably has the most diverse global collection of *Fragaria*, including wild collected American octoploids, European and Asian diploid and polyploids. In addition to heritage American cultivars, advanced breeding lines and other unusual genotypes are included.

The Corvallis genebank distributes between 800 and 1,000 strawberry accessions annually, depending on requests. About 25 % are sent to collaborators outside the United States and the remainder are domestic distributions. Since 1981, the genebank staff members have distributed strawberries to 51 countries, each of the 50 United States, and 2 U.S. territories. Plants, runners, leaves, DNA, seed, fruit, and *in vitro* cultured plantlets are distributed. Material transfer agreements are not required.

Besides *Fragaria*, the unit also preserves genetic diversity of 29 fruit, nut, and specialty crop genera, including *Actinidia, Corylus, Cydonia, Humulus, Mentha, Pyrus, Rubus, Ribes, Sambucus, Sorbus,* and *Vaccinium*.

5.2 Canada

The Agriculture and Agri-Food Canada (AAFC). Canadian Clonal Genebank at Harrow, Ontario, houses the Canadian national strawberry collection. This facility was created in 1989 at Trenton, Ontario, and was relocated to Harrow, in 1996. The base funding of this facility is federal, appropriated annually through the budget for AAFC. Funding is also available from a program called Matching Investment Institutive wherein the federal government will match any funds provided by industry for a specific project. The genebank staff includes a scientist, a horticulturist-curator, a technical support person who oversees the tissue culture/pathogen elimination program, and 3 other technicians (6 FTE). The mandate of the genebank is to protect and preserve diversity of Canadian fruit-crop plants and their wild relatives. They acquire, maintain, evaluate, research and document plant genetic resources for specifically assigned genera. They provide the fundamental building blocks for crop cultivar development and plant genetic resource studies.

The primary strawberry collection (Fig. 9) is maintained as potted plants in an aphid-proof screenhouse. The secondary collection is preserved as tissue cultured plantlets on site. Approximately 25% of the accessions are backed up. For remote backup of the collections, and for evaluation, the Canadian Clonal Genebank collaborates with AAFC strawberry research and breeding programs at Kentville, Nova Scotia, St. Jean, Quebec, and Agassiz, British Columbia, and with scientists at the University of Guelph and the University of Saskatchewan.

The Canadian Genebank distributes 393 accessions per year on average, which amounts to 1703 accessions per year. Plants are distributed as rooted runners, crown divisions, or dormant plants. Seed, fruit, runners, leaves for DNA extraction, and

tissue cultures are also distributed. Domestic clients account for 85% of the distribution and the remaining 15% are international.

One of the features of the Canadian Clonal Genebank is the preservation of representatives of wild native Canadian strawberry species. *F. chiloensis* native to the western Canadian coast and native *F. virginiana,* from interior provinces are preserved. In addition, cultivars released by Canadian scientists are maintained.

The facility also preserves genetic diversity of *Malus, Pyrus, Prunus, Rubus, Ribes, Sambucus,* and *Vaccinium.*

5.3 Russian Federation

The national strawberry genebank for the Russian Federation resides at the N. I. Vavilov All-Russian Research Institute of Plant Industry (VIR), B. Morskaya St. 42, 190 000, St. Petersburg, Russian Federation. This is a governmental facility. The primary purposes of genebank are collection, conservation, characterization, evaluation, and documentation of fruit germplasm.

The primary collection is stored in the field with a small amount in a secondary on-site collection in tissue culture. Species are represented by seedlots that are stored at -10 °C, 80% RH, in hermetically sealed aluminium foil bags. Viability is tested every 5 years. The plant materials are not safety-duplicated in a remote genebank although collaborations are maintained with breeding programs at Polar Branch of VIR, Murmansk Region, and the Maikop Experiment Station of VIR, Krasnodar Territory. The St. Petersburg genebank distributes about 80 accessions annually. About 60% is distributed domestically.

The VIR station in St. Petersburg has the responsibility for preservation of all of the agronomic and horticultural genera of interest to the Russian Federation.

5.4 Germany

The Federal Centre for Breeding Research on Cultivated Plants, Institute of Fruit Breeding in Dresden-Pillnitz, conserves plant genetic resources for strawberries in Germany. This facility is located on the Elbe River in southern Germany. The mission of the genebank is collection, conservation, evaluation and documentation of genetic resources of fruits. The spectrum of the collection includes: German cultivars including new German selections; cultivars with a social cultural, local, or historical relation to Germany, and cultivars with important pomological traits. Wild species are also represented.

The primary active strawberry collection (Fig. 10) is kept in a box system outside in the orchard. Two boxes of 3 plants (6 total plants) are maintained for each accession. The plants are replaced every two years. Spraying and fertilization is performed in accordance with integrated production technology. The boxes of most strawberries are moved to the ground and covered with straw for winter hibernation, while frost sensitive genotypes are temporarily moved into the greenhouse. The secondary on-site collection of strawberries is preserved as cold storage of *in vitro* culture of plantlets, and cryopreservation of meristems is in progress. The facility also manages the German Federal Register of 640 strawberry cultivars.

The Dresden genebank is a part of the European Cooperative Programme for Crop Genetic Resources Network (COST 863) and works closely with 28 other European genebanks for remote back-up collections and evaluation of cultivars. A computer database has been developed to coordinate inventories and evaluation information between genebanks. In the frame of Council Regulations No 870/ 2004 a new EU Project AGRI GEN RES 036 ‘’European small berries genetic resources’ including 10 partners was accepted and will start at the end of the year 2007.

The Dresden genebank also preserves *Malus, Prunus, Pyrus*, and *Sorbus* accessions.

5.5 Spain

Centro de Investigación y Desarollo Agrario C.I.D.A., Finca Cortijo de la Cruz, 29140 Churriana, Málaga, Spain. The strawberry genebank at CIFA Málaga belongs to the Andalusian Institute of Fishery and Agrarian Research and Biological Agriculture (IFAPA). The mission of the genebank is to obtain, establish, preserve, identify, and evaluate the genus *Fragaria*. Most of the accessions are hybrid *F. ×ananassa* cultivars and breeding lines and about one third of the collection is other Fragaria species. Plants are exchanged to improve and enlarge the collection. The primary collection is maintained in pots with three replicates. A secondary back-up collection is maintained as *in vitro* cultures. Cryopreservation of a core collection is in progress. Data on characterization is being performed according to COST 836 WG1. Genetic marker data, including isozymes, AFLP, microsatellites, EST, is under study with collaborators at universities in Málaga and Córdoba, Spain.

The CIFA Málaga is a part of the European Cooperative Programme for Crop Genetic Resources Network (COST 836), and works closely with 20 other European genebanks for remote back-up collections and evaluation of cultivars. A database has been developed to coordinate inventories information between genebanks.

5.6 Chile

This country currently has no governmentally sponsored strawberry genebank. Material that had been collected in the ‘90s through expeditions in southern Chile with US and Japanese scientists and that was held at the National Institute of Agricultural Research (INIA), substation Cauquenes, suffered from lack of funding in recent years and could not be maintained properly; thus, this important genebank is no longer operating. Major strawberry collections are maintained at University of Chile, Santiago, and at the University of Talca. The mission of both collections is breeding and neither collection is expected to be active under the International Treaty. The University of Chile, Santiago, has about 190 strawberry genotypes and the University of Talca has about 549 genotypes. Their collections consist of native wild species, landraces (mainly *F. chiloensis*), or crosses under their own ownership for breeding purposes. Plants are maintained in containers under cover (Fig. 5). Part of the collection is backed up as *in vitro* cultured plants. Some germplasm is preserved as seeds.

6. Regional conservation strategies

Regional conservation strategies include groupings based on continental location. These strategies aim at identifying key collections of important crops on a region-by-region basis. Nine regions have been defined: Americas, Central Asia and the Caucasis, East Africa, Europe, Pacific, South Africa, South /Southeast/ East Asia, West Asia and North Africa. The Americas have identified strawberries as a key crop in their regional conservation efforts. Canada, the United States, and Mexico each have strawberry collections at their genbanks. Chile, Peru, Brazil and Argentina have interest in the conservation of this crop as well.

Fig. 12. Campbell Davidson (right) discusses regional conservation Strategies.

7. Importance of collections

Several categories of strawberry genetic resource need to be considered for inclusion in world genebanks: 1) wild related species of strawberry, 2) land races, 3) obsolete improved cultivars, 4) advanced improved cultivars, 5) breeding/research materials with specific traits of interest, 6) inter-specific derivatives, 7) mapping populations, and 8) transgenics.

The highest priority for genebanks should be placed on obtaining representatives of the complete eco-geographical range of the native strawberry species. Whenever possible, populations and species should be represented by seed, but individual clones with known unique characteristics should also be maintained. Other criteria for deciding what should be preserved include: 1) the published data base, 2) a unique contribution to stored genetic diversity, 3) the vulnerability of the source population, 4) potential or known breeding value, 5) potential or known research value and 6) demonstrated commercial value. World genebank collections should be periodic reviewed using these criteria, to identify the smallest collection that adequately represents the existing genetic diversity. Comprehensive cultivar pedigrees should be developed and documented to aid in this endeavor.

7.1 Completeness

For the greatest application to breeders now and for the future, the available primary cultivated strawberry gene pool should be composed of developed cultivars of *F.* ×*ananassa* adapted to particular regions and having specific flowering, fruiting and plant characteristics. Regional strawberry breeders have been using seedlings of adapted cultivars for specific adaptation in their area. In the past 20 years, octoploid species native to the Americas have been identified and collected in multiple expeditions (Annex 10). *Fragaria chiloensis* has been collected and preserved from the most northerly latitude (59^{o}N) in Alaska through the western coast of Canada, Washington, Oregon, and California, and in Chile south of 45^{o}S. In addition *F. chiloensis* subsp. *sandwichensis* from Hawaii has been collected. The strawberry landrace of *F. chiloensis* subsp. *chiloensis* f. *chiloensis* has been collected from Chile and the Huachi, from Ecuador.

F. virginiana has been collected from north Ontario, BC, to Fairbanks, Alaska in the north, through the Rocky Mountains, in the Pacific Northwestern states and in the southeastern states. Some wild diploids have been obtained from Europe, the US, and Asia. A few higher ploidy plants have been collected from Asia.

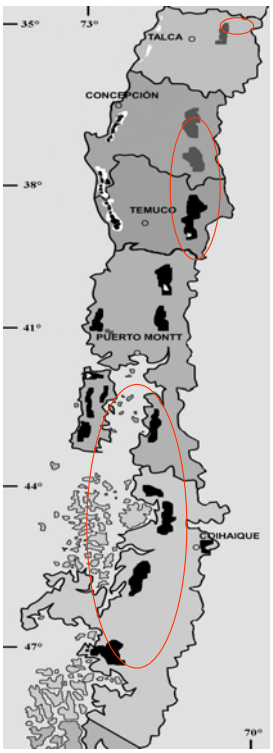
Two major genebanks exist in North America: in Canada and the United States. They preserve a broad diversity of *Fragaria virginiana* and *F. chiloensis* representing the primary gene pool for cultivated strawberry diversity. COST is preserving wild European species. *F.* ×*ananassa* comprises about 66% of the total composition of the global genebanks (Annex 8). Wild species represent about a third, with *F. chiloensis* the most, a combination of miscellaneous species next, and *F. virginiana*, and *F. vesca* following.

Fig. 13. Gunter Staudt, German strawberry taxonomist, collecting strawberries in China in 1996.

7.2 Gaps in collections

Many of the genebanks that responded indicated that gaps existed in their collections. Seven indicated that species coverage was incomplete (Annex 11). Three indicated that population sample representatives of species were insufficient. A major *Fragaria* genebank needs to be located in Asia, possibly China, where relatively few collections of native diploid and polyploid wild species have been made or accessible to research efforts. Secondly, a genebank in South America, possibly Chile, should be designated. The *F. chiloensis* subsp. *chiloensis* f. *chiloensis* landrace that provided the maternal genotype for the economically important *F.* ×*ananassa* is cultivated there. Efforts should be made to facilitate international access of this germplasm. Besides the difficulty of inter-country movement of genetic resources due to varying phytosanitary requirements and limited availability of funds, the politics of accessibility is involved.

Fig. 14. Gaps (2007) where *Fragaria* needs to be collected in Chile.



There is a large gap of available native Chilean plant materials from Northern Andes locations: 34°S / 70.5°W to 35°S / 70.5°W; from Southern Andes locations: 39°S / 71.5°W to 41°S / 72°W and 41°S / 72°W to 45°S / 72°W.

Several significant germplasm gaps exist in the worldwide collections. One listing has been defined by the USDA Small Fruit Crop Germplasm Committee (http://www.ars-grin.gov/npgs/cgc-reports/smallfrt.htm). These include: 1) Asian 2x and 4x and higher ploidy species, 2) NW Alaskan octoploids, 3) *F. virginiana* from NW and NE Canada, the mid-western and SW US states below Colorado, 4) *F. moschata* and *F. viridis* from eastern Europe, and 5) heirloom cultivars that possess unique genetics. There is also a need to develop and store mapping populations of *F. vesca* and *F.* ×*ananassa* that can be made available to researchers across the world working on the *Fragaria* genome. The maintenance of a collection of transgenic plants in an accessible collection would also be desirable. Unfortunately patent and licensing issues currently restrict this possibility.

7.3 Identification and characterization

Taxonomic classification through morphology is used in each of the strawberry genebanks (Annex 12). The IPGRI strawberry descriptor list is used by 60% of the genebanks. GRIN and in house descriptor lists are used by other countries. Only small collections or portions of collections are fully characterized.

8. Condition of collections

Strawberry genebanks in North America and Europe function well, have acceptable storage protocols, methods and conditions (Annex 13). Funding has limited on-site secondary collections. For example, the US genebank has reduced the non-core strawberry collection to one pot per genotype. This is undesirable, but is brought on by financial, labor and space restrictions. Funding for basic maintenance operation of the major genebanks is minimally sufficient at these genebanks, but flat or decreasing budgets are the norm and their effective spending power is being eroded by inflation.

The health of the strawberry genebank collections (Annex 14) is minimally sufficient. Virus and virus-like-organisms are tested by enzyme linked immunosorbent assay (ELISA), biological indicators, or PCR in 50% of the collections. The other half of the genebanks are unable to test their collections and eradicate diseases. The staff of these genebanks requires training and assistance to improve the health status of their collections (Annex 14). The US genebank, and others, are turning to out-sourcing for PCR pathogen testing procedures because of insufficient staffing and resources for in-house performance of these operations.

Plant evaluation activities tend to be performed using non-base funding which curators and scientists apply for annually or periodically. Recently extramural support or grants from governmental agencies, private commodity commissions, or other interested has been more difficult to obtain, so evaluation of strawberry genetic resources has proceeded slowly.

8.1 Distribution

Strawberry genebanks have options for plant materials distribution (Annex 15, 16). Strawberry propagules include distribution of seed, pollen, dormant crowns, runners, tissue cultured plantlets, and cryopreserved meristems. Dried and lyophilized leaves can also be distributed for DNA extraction. More than 1000 accessions of strawberries are distributed from global strawberry genebanks annually.

8.1.1 Physical availability

Other than seed, clonal strawberry propagules are only available in the appropriate season. Sometimes out-of-season requests can require as much as a year of preparation before the plant materials will be available for shipment. Runners and plants can be sent during the mid-summer growing season; dormant crown divisions during winter. Out-of-phase requests require longer processing time.

Besides the seasonality of requests, these propagules must be obtained from pathogen-negative germplasm that are grown in conditions without pests so that health and safety regulations of an importing country (as mentioned in Section 3.5) can be satisfied.

Standard phytosanitary certification procedure requires that plants be tested periodically for specific diseases (Table 3.5.1). An import permit (IP) is obtained from the health plant inspection service of the importing country. This IP states what specifically the plant material has to be tested for, or found free of. An inspector, from an independent agency than the genebank staff, examines the plant material and testing record for the proposed shipment. The inspector interprets the wording on the IP. If, in the opinion of the inspector, the plant material complies with the requirements of the IP, the inspector will approve the shipment. The inspector will then prepare a phytosanitary certification (PC) with an official seal. Both the original IP and PC must accompany the plant materials to the port of entry of the importing country. There, a custom's broker may be secured to "walk" the plant material across the border, or the individual importer can do so. The plants and papers are examined by the agricultural inspection service. Plant material that meets the criteria of the inspector is permitted entry; non-compliant plant material is destroyed prior to admission into the country. After receipt of the plant material some countries require a period of quarantine or post-entry quarantine prior to general distribution into domestic exchange.

8.1.2 Breeding, accessibility, and past distribution

Strawberry cultivars often have a short commercial lifespan relative to tree fruit. Over the past 20 years, strawberry research and breeding has greatly changed.

Although the introduction of new strawberries can be hastened, it usually requires 8 to 15 years of breeding, selecting and testing. New regional cultivars replace old ones every five to ten years. A broad genetic resource base is needed to support the rapid turn-over of cultivars to prevent in-breeding. However, an increasing number of strawberry researchers only release cultivars with intellectual property rights such as plant breeder's rights, patents, or at least commercial propagation restrictions or trademarked names.

While this intellectual property has provided a source of revenue for research and breeding programs, plant genetic resources and advanced breeding lines that were previously freely shared between academic research programs are now restricted. Material transfer agreements are required. Fewer strawberry researchers and breeders are supported in academic, publicly responsible positions. Private industry has taken up research and breeding of new strawberries. Outdated cultivars from private programs in some programs are destroyed to prevent competition from gaining access to "trade secrets." These cultivars are not being saved for the improvement of humanity. Yet, academic and private programs still request plant material from major genebanks, though their releases may not be accessible in return.

During the past 5 years, the major genebanks in North America and Europe have distributed between 80 and 1,000 accessions annually. Between 20 and 25% of the distributions are shipped internationally and 75 to 80% are shipped domestically. Between 10 to 90% of distribution is foreign, depending on the genebank. The majority of distributions are sent to the public sector, although non-governmental organizations, farmers, and the private sector are also recipients (Annex 15). Strawberry germplasm is distributed freely by most genebanks although MTAs are required with the advent of recent international treaties. On-line listings or catalogues are partly available for most genebanks. The US genebank holdings are fully on-line.

Over the past 25 years, the Corvallis Genebank has distributed the world's greatest quantity of strawberry accessions, shipping about 15,000 plants, runners, seed, tissue cultures, and leaves to 51 countries, each of the 50 United States, and two U.S. territories. Canada, the EU, and Russia also distribute significant amounts.

Recent changes in the quarantine requirements of the European Union have greatly affected world distribution of strawberry propagules. To enter the EU countries, plants must now be tested for phytoplasmas, in addition to previously required virus, and viroid tests. Seed must now be obtained from pathogen-free sources. Thus, seeds collected from wild, untested plants are now unacceptable in the EU. In addition, plants must not only be stated to be free of white fly, but must be observed to be grown for 90 days free of European white flies (*Bernisia tabaci* Genn.) prior to shipment.

Many other countries have adopted EU regulations on small fruits so these regulations also apply to some South American countries, South Africa, Australia, and New Zealand.

8.2 Safety duplication

European accessions have safety duplication through collaborative inter-country cooperation (Table 4.1, Annex 17). About half of the genotypes are backed up in multiple countries. The Russian Federation, the Czech Republic, and the US have remote back-up facilities within country borders. The Canadian and Chilean collections are not officially backed-up, although the US genebank has some representation of native collections from these countries.

The US genebank has only about 20% of its total (plant and seed) collection at the remote Ft. Collins, Colorado back-up facility. With non-core collection in one pot only, this represents a serious potential for irreplaceable genotype loss over time.

Plant breeders could be polled periodically as a safety duplication of contemporary cultivars, but over the long term, cultivars rotate out of favor and are phased out.

9. Genebank management needs

Almost all of the 19 genebanks that responded to the questionnaire stated that they did not have written procedures or protocols for some of the standard genebank functions (Annex 18). Health, distribution, and safety duplication protocols were the most frequent undocumented procedures.

Resources are a large constraint for strawberry genebanks (Annex 19). Six genebanks stated that there were insufficient resources for routine operation. Seven mentioned that retention of staff was insufficient or bad. Active support from users was a concern for 5 genebanks, although more than half of the genebanks stated that the level of use by breeders was adequate to high. Lack of equipment and lack of facilities or space for collections was also a large concern.

The major constraints listed by strawberry genebanks are found in Annex 20. Resources for additional staff, facilities, and improving the health status of the collections were frequently mentioned. Technical difficulties of communicating within the network were also mentioned.

The collections in China face constraints. Conservation of wild strawberry genetic resources is potentially in danger. Accessibility to Chinese species is limited or denied. Representatives of these genebanks did not participate in the Corvallis workshop and specific details on these genebanks were not available to the expert committee.

The two genebanks in Chile are managed by private university interests. Chile has significant native genetic resources that should be preserved in a Chilean national genebank.

9.1 Highest priorities for support

1. The committee notes that the genetic resources of China and Chile could be in high risk of loss. This plant material is not secured as *ex situ* collections in national or regional genebanks. These countries' genetic resources represent invaluable plant material for research and breeding efforts. This plant material is inaccessible or has only limited accessibility for foreign requesters. The expert committee recommended that strawberry collections in these countries be upgraded to genebank status and adopt standard protocols for strawberry genetic resource preservation as presented in this strategy. National support for this effort should be encouraged. Trust resources could assist in this development.
2. The committee recognized that resources for the 19 respondent genebanks are insufficient for basic operational needs. A grant should be established for genebanks to apply to upgrade virus, viroids, and phytoplasmas detection and elimination procedures. The clean stock produced by this grant should then be internationally accessible for global use.
3. The European Union should establish a quarantine facility with the capability of accepting foreign strawberry genetic resources so that clean-up procedures could be performed within Europe, rather than expecting donating countries to provide this service.

4. A global computer database of strawberry collections should be established. This could be done through linking present on-line databases. More effort needs to be put into maintaining electronic inventories and databases of the available strawberry genebank lists.
5. Unified character data should be adopted. IPGRI descriptor list should be adopted by each of the global genebanks.
6. Grants for training of staff should be available through grants to genebanks lacking procedural knowledge of standard genetic resource preservation protocols. Other genebanks that can provide training are listed (Annex 21) and could provide this training service.

9.2 Capacity of strawberry genebanks to meet Trust's eligibility principles

Several countries of which collections have been given high priority for support have not yet signed or ratified the International Treaty. Therefore, conditions for access and benefit sharing of PGRFA supported by the Trust still need to be agreed and clarified. Institutions in countries which do not meet the Trust's eligibility principles/criteria with regard to the International Treaty of PGRFA may be allowed to sign the "Solemn Undertaking for access or conservation" (Annex 22).

10. Conclusions

The expert committee unanimously recommended that two strawberry genebank centers should be established: one in Asia (China, if possible) and one in South America (Chile, if possible). These centers could work in conjunction with North American and European genebanks already in operation. If these new genebank centers can not be established for financial or political reasons, at least storage conditions for strawberries in Chile, China, and eastern territories of the Russian Federation need to be improved and should be supported. This is important because critical endangered native wild and landrace genetic resources now exist in those regions, and should be collected and preserved before they are lost.

The committee also suggested to:

- collect 1) Asian diploid and higher ploidy species, 2) NW Alaskan octoploids, 3) *F. virginiana* from NW and NE Canada, the midwestern and SW US states below Colorado, 4) *F. moschata* and *F. viridis* from eastern Europe, and 5) heirloom cultivars that possess unique genetics.
- develop and store mapping populations of *F. vesca* and *F.* ×*ananassa* that can be made available to researchers across the world working on the *Fragaria* genome.
- improve health of plants in 19 country genebanks.
- avoid loss of unique material presently in global genebanks.
- improve the level of safety duplication through alternative storage techniques.
- standardize ontology for phenotypic and genotypic characterization of the collections.
- optimise documentation of the collections, in order to improve accessibility, and as a tool for management of the collections from a global perspective. Insure web accessibility.
- train staff in non-major genebanks regarding alternative storage techniques and health maintenance.
- establish a European quarantine facility for strawberries to detect and eliminate viruses, virus-like agents, viroids, and phytoplasmas.

- recognize Antoinne Duchesne, botanist from France in the mid-1700's, with a plaque at the location in Versailles, France, where he was living and where in his garden, *F. ×ananassa* was first found.

The participants at the Corvallis workshop expressed their interest to form a global information network to coordinate the global conservation of strawberry genetic resources. Globally viewed inventories of accessions, and the country where they reside would be a great benefit to global strawberry research. This network ideally could link COST genebank inventories with those in the United States and Canada, and elsewhere.

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Fig. 15. Strawberry genebank curators in 2008, (L-R) M. Hofer (Germany), M. Luffman (Canada), K. Hummer (US), J. Retamales (Chile).

Annex 1. Corvallis Workshop Program

Global Strategy for the
Conservation of Strawberry Genetic Resources
USDA ARS National Clonal Germplasm Repository
33447 Peoria Road, Corvallis, Oregon 97333
phone: 541.738.4200
Committee Meeting: 5, 6, and 7 July 2006

Objectives:

- To consult the representatives of relevant strawberry collections in order to develop a strategy for the efficient and effective conservation of strawberry genetic resources
- To access the state of art of strawberry conservation in the world and to identify collections or networks which may be eligible for long-term support by the Global Crop Diversity Trust
- To discuss conservation standards and criteria for long-term support from the Trust

Schedule

Wednesday 5 July 2006

18:00 – 20:00	Corl House, Corvallis Oregon.
Evening Reception	Introductions, discussion, light meal will be served

Thursday 6 July 2006

7:45	Meet Vans at Super 8 Hotel Travel to HCRL, 3500 Orchard Way
8:00 – 10:00	Location: USDA ARS Horticultural Research Research Laboratory Video teleconference with Cary Fowler, Brigitte Laliberté, Global Horticultural Trust, IPGRI, Rome.
10:00 – 10:30	Break transportation to USDA ARS NCGR
10:30 – 12:00	Presentations of committee members
12:00 – 13:00	Working lunch at Repository
13:00 – 15:00	Discussion of survey results
15:00 – 15:15	Break
15:15 – 17:00	Working groups discuss writing assignment Vans to hotel
18:30 – 21:30	Dinner at Big River Restaurant, Corvallis Vans return to Hotel

Friday 7 July 2006

7:45	Meet Vans at Super 8 Hotel Travel to NCGR
8:00 – 10:00	Discuss genebank protocols (primary, alternatives, long term)
10:00 – 10:30	Break
10:30 – 12:00	Discuss international IT linkage; safe movement of germplasm
12:00 – 13:00	Working lunch at Repository
13:00 – 15:00	writing in teams
15:00 – 15:15	Break
15:15 – 17:00	Report back to the group Vans to hotel
18:30 – 21:30	Dinner on own

Annex 2. Expert Strawberry Committee

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Annex 3. *In vitro* culture protocol for *Fragaria*

Reed (2004) follows this procedure at the Corvallis Genebank.
Medium: *In vitro* culture plantlets of *Fragaria* are grown on Murashige and Skoog (Murashige and Skoog, 1962) (MS) medium with per liter: NaH_2PO_4 (170 mg), adenine sulfate (80 mg), N^6benzyladenine 1 mg, IAA 1 mg, GA_3 0.01 mg. Growth room conditions are 16 h photoperiod (25 $\mu mol \bullet s^{-1} \bullet m^{-2}$) at 25 ^oC.

Initiation/surface sterilization: Fragaria explants are taken from recently formed runners of screenhouse-grown plants. Plantlets are surface sterilized by placing them in a 10% bleach solution (bleach is 5.25% sodium hypochlorite) with 0.1 ml/l Tween 20 and shaken on a rotary shaker for 10 minutes. Explants are then removed, rinsed twice with sterile water, and checked for contaminants. Some plants do not produce very many runners. A 500 PPM GA_3 spray combined with long day conditions has been helpful in inducing runnering in some of these plants. If runners from field plants are used, small meristems (0.5 mm) should be taken to aide in the elimination of viruses.

Contaminant detection: To detect internal contamination, explants are placed in 1/2 strength liquid MS medium and a pH of 6.9. Contamination will look like cloudiness or flocculent growth in the medium. Use standard growing conditions in these steps. If no contamination shows after one week then move the plants to multiplication medium. Plant shoots on regular medium, streak and place trimmed bases on 523 detection medium (Viss et al., 1991). If contamination shows, recollect new tips, sterilize and rinse as before. If a second group is all contaminated, consider antibiotic treatment (Tanprasert and Reed, 1997a; 1997b). Multiplying plants suspected of contamination are streaked on petri plates containing 523 medium [sucrose 10 g/l, casein hydrolysate 8 g/l, yeast extract 4 g/l, KH_2PO_4 2 g/l, $MgSO_4 \bullet 7H_2O$ 0.15 g/l, and agar 8 g/l (gelrite 6 g/l)] or nutrient agar. The pH of the detection medium is adjusted to 6.9 before autoclaving. The base of each explant is streaked on the plate before planting in 16 mm tubes containing 5 ml multiplication medium. The plates are incubated for 48 hours at 24 ^oC. Plantlets showing contamination on the plates are discarded. Nutrient agar or potato dextrose agar may also be used as detection media.

Multiplication: Plantlets are multiplied on base MS medium (Appendix). Specific accessions may improve with alternative growth regulator combinations but this general formula works well for most.

Rooting: Healthy plants are rooted on regular base medium without hormones or with 0.01 mg/l IBA

Cold storage of in vitro-grown plantlets: Plantlets to be stored are placed on MS medium without additives or growth regulators or with 0.5 mg/l N^6 benzyladenine inside plastic *in vitro* culture bags (medium with agar 3.5 g/l, Gelrite 1.45 g/l) or well sealed tubes. Plants are held in the growth room for 1 week and then cold acclimated for 1 week. The bags are then placed in a storage room at 4 ^oC in low light. Plantlets in *in vitro* culture bags store for an average of 15 months with a range of 9 to 24 months (Jungnickel, 1988; Reed, 1995).

Annex 4. Strawberry indexing procedures

(adapted from Martin, 2004).

Agent/Disease	BioAssays[z]	Laboratory Tests	Tests that need validation[y]
Arabis mosaic	*C. quinoa*	ELISA	
Aster yellows phytoplasma		PCR	ELISA
Fragaria chiloensis	Cucumber	ELISA	
Raspberry ringspot	*C. quinoa*	ELISA[x]	
Strawberry chlorotic fleck	EMK		
Strawberry crinkle	UC-5 -6, 'Alpine'		PCR
Strawberry feather leaf	Alpine'		
Strawberry green petal phytoplasma		PCR	ELISA
Strawberry latent C	UC-5, EMC		
Strawberry latent ringspot	*C. quinoa*	ELISA	
Apple mosaic	UC-5, -10		
Strawberry lethal decline	Alpine'		PCR
Strawberry marginal chlorosis			PCR
Strawberry mild yellow edge	UC-4, -5 'Alpine' Negative on UC-6	ELISA	PCR
Strawberry mottle	UC-5, 'Alpine'		PCR, ELISA
Strawberry mycoplasma yellows			PCR
Strawberry pallidosis	UC-10, -11		DsRNA, PCR
Strawberry pseudo mild yellow-edge	UC-4, -12, 'Alpine'		
Strawberry rickettsia yellows			
Strawberry veinbanding	UC-5, -6, 12 'Alpine'		PCR, ELISA
Tobacco necrosis	*C. quinoa*	ELISA	
Strawberry necrotic shock	*C. quinoa*	ELISA[x]	
Tomato black ring	*C. quinoa*	ELISA[x]	
Tomato ringspot	*C. quinoa*	ELISA[x]	

[z]Sap and graft transmissions should be done in the early spring and one should use young vigorous indicator plants for graft assays. BioAssay by sap transmission is less reliable than ELISA tests and if possible ELISA testing should be done to confirm negative BioAssay results.

[y] Tests that need validation. These tests reported in the scientific literature to be able to detect the given pathogen, however, at this time only one or a few isolates of the pathogen have been studied. A broader range of isolates need to be detected with the described assay to ensure its usefulness in detecting a broad range of isolates of the pathogen before the test can be recommended for certification or quarantine purposes.

[x]Indicates virus is quite variable and a single antiserum may not detect all isolates. This is especially true if one is using monoclonal antibodies.

Annex 5. Questionnaire

Strawberry Conservation Strategy Survey
March 2006

1. Background

The Global Crop Diversity Trust is undertaking a series of studies to support the development of international conservation strategies for different crops. As such strategies evolve, they will provide a basis for the allocation of resources from the Trust to the most important and needy collections.

This questionnaire has been developed in order to seek the advice and input of representatives of the world's major strawberry collections in the development of the strawberry conservation strategy. In particular the questionnaire aims to assess the status of strawberry conservation throughout the world.

As a key curator of a strawberry collection, we kindly request you to complete the sections 1-19 of the questionnaire. We estimate that his procedure may take approximately 1 hour of your time. We appreciate your patience. If there are no *ex situ* strawberry collections in your institute, please can you complete sections 18-19 only. The USDA Agricultural Research Service, National Clonal Germplasm Repository (NCGR) is responsible to coordinate the development of a global strawberry conservation strategy in order to support the efficient and effective conservation of strawberry germplasm. Please return the questionnaire to Dr Kim Hummer at NCGG, within the next 2 weeks.

Dr. Hummer and the Trust are keen to have your active participation in the development of the strawberry conservation strategy and will be pleased to keep your informed on its progress. If you have any questions about this questionnaire or about the proposed strategy in general, please contact:

Dr Kim Hummer, Research Leader
USDA Agricultural Research Service (ARS), National Clonal Germplasm Repository (NCGR)
33447 Peoria Road, Corvallis, Oregon 97333, USA
Tel: 541.738.4201, fax: 541.738.4205, Email: khummer@ars-grin.gov

2. Information about your organization

2.1 Name and address of your organisation holding/maintaining the strawberry collection			
Address:			
City:		Postal Code:	
Country:			
Web site:			
2.2 Curator in charge of the strawberry collection			
Name:			
Address:			
City:			
Telephone:		Fax:	
Email:			
2.3 Contact details of respondent to this questionnaire (only if he/she is not the curator of the strawberry collection)			
Name:			
Address:			
City:			
Telephone:		Fax:	

Email:	

2.4 Date of response of this questionnaire: _____

3. Additional key contacts for the strawberry germplasm collection

Name(s)	Title(s)/Function(s)	Email/Address

4. Description of your organization

4.1 Please describe your organization

- ☐ Governmental organization
- ☐ University
- ☐ Private organization
- ☐ Other (please specify): _____

4.2 Is the institution in charge of the strawberry collection the legal owner of the collection?

☐ YES ☐ NO

4.2.1 If NO, who is the owner (including no owner identified)?

_____

4.3 Is the strawberry collection subject to the terms and conditions of the International Treaty on Plant Genetic Resources for Food and Agriculture? ☐ YES ☐ NO

4.3.1 If NO, is expected to become under the International Treaty in the near future?

☐ YES ☐ NO

4.3.1.1 If YES, indicate expected date: _____

5. Overview of your strawberry collection

5.1 Please describe the main objectives of the strawberry collection (long-term conservation, working collection, breeding collection etc**.):**

_____

_____

5.2 Indicate the species and the respective number of accessions from the strawberry germplasm types that are included in your collection (Please write the number of accessions in brackets after each species name, e. g. *F. vesca* (30), *F. chiloensis* (15), etc.)**:**

Type of strawberry germplasm	Species name (number of accessions per species in brackets)
Wild related species of strawberry	*F. chiloensis* *F. vesca* *F. virginiana* *F. ×ananassa*

Type of strawberry germplasm	**Species name (number of accessions per species in brackets)**
	Others
Landraces	*F. chiloensis* *F. vesca* *F. virginiana* *F. ×ananassa* Others
Obsolete improved cultivars	*F. vesca* *F. ×ananassa* Others
Advanced improved cultivars	*F. vesca* *F. ×ananassa* Others
Breeding/research materials	
Inter-specific derivatives	
Unknown	
Other	

5.3 Please indicate the share (in %) from each specific type of germplasm that is AVAILABLE for distribution:

Type of strawberry germplasm (where known**)**	**% available for distribution**
Wild related species of strawberry	
Landraces	
Obsolete improved cultivars	
Advanced improved cultivars	
Breeding/research materials	
Inter-specific derivatives	
Unknown	
Other	

5.4 Origin of the strawberry collection: please indicate the proportion (%) of accessions on the total amount that were... *(Note: the sum should be 100 %!)*

Origin	**Proportion %**
...collected originally in your own country (national origin)	
...collected originally in your own region (regional origin)	
...introduced from a collection abroad	
...from other origin (please define the origin):	

5.5 Are there major gaps in your strawberry collection? Please indicate major gaps concerning your strawberry collection:

Species coverage of the crop: ☐ YES ☐ NO
Population (sample) representation per species: ☐ YES ☐ NO
Ecological representation of the species: ☐ YES ☐ NO
Other, please specify the gap concerning your strawberry collection:

_____

5.5.1 If there are major gaps, please provide details on the plans to fill these gaps:

_____
_____
_____

6. Aspects on the potential of the strawberry collection

6.1 What would you consider to be the most interesting aspects of your strawberry collection, making it unique?

_____
_____
_____
_____

6.2 Please describe the main potential/importance of your strawberry collection for use and breeding:

_____
_____
_____
_____

7. Conservation status (germplasm management)

7.1 Please indicate the proportion (in %) of the strawberry accessions maintained under different facilities: *(Note: if the same accessions are maintained under more than one storage condition the sum may exceed 100%)*	**Percentage %**
Short-term storage conditions	
Medium-term storage conditions	
Long-term storage conditions	
Other, please specify:	

7.2 Please indicate the proportion (in %) of the strawberry accessions conserved as: *(Note: if the same accessions are stored as different types of germplasm the sum may exceed 100%)*	**Percentage %**
Seeds	
Field accessions	
In vitro	
Cryopreservation	
Pollen	
DNA	
Other, please specify:	

7.3 Please describe the MAIN storage facility available for your strawberry collection:
*(If you have **more than one** facility, please use the fields for 'additional facilities 1-3' too)*

	Main Facility 1	**Additional facility 1**	**Additional facility 2**
Type of facility			
Temperature			
Relative Humidity (%)			
Packing material			
Other, please specify:			

	Additional facility 3	Additional facility 4	Additional facility 5
Type of facility			
Temperature			
Relative Humidity (%)			
Packing material			
Other, please specify:			

7.4 Please mark for which activity you have established a genebank management system or written procedures and protocols:

- ☐ Acquisition (*including collecting, introduction and exchange*)
- ☐ Regeneration
- ☐ Characterisation
- ☐ Storage and maintenance
- ☐ Documentation
- ☐ Health of germplasm
- ☐ Distribution
- ☐ Safety-duplication
- ☐ Other please specify: _____

7.5 In case you have procedures and protocols, are you able to provide the Global Crop Diversity Trust with this information (i.e. provide a copy)? ☐ YES ☐ NO

7.6 Please describe your quality control activities, in terms of frequency, protocols/methods and actions upon results:

Activities	Description of quality control
Germination tests:	
Viability testing:	
Health testing:	
True-to-typeness :	
Other, please specify:	

7.7 Is the strawberry collection affected by diseases that can restrict the distribution of the germplasm?

☐ YES ☐ slightly, only few accessions ☐ NO

7.7.1 If you indicated YES or slightly above, are knowledge and facilities available at your institution for test and eliminate these diseases? ☐ YES ☐ limited ☐ NO

7.8 Indicate the proportion (%) of each germplasm type that requires urgent regeneration, apart from the routine regeneration:

Type of strawberry germplasm	% of strawberry accessions with urgent regeneration need
Wild related species	
Landraces	
Obsolete improved cultivars	
Advanced improved cultivars	
Breeding/research materials	
Inter-specific derivatives	
Unknown	
Other, please specify:	

7.9 Please indicate the current situation of the strawberry collection with respect to the following conditions: (*where: 1 = high/good, 2 = adequate/moderate, 3 = not sufficient/bad, NA = not applicable*)

Condition	Current situation	Expected situation in 2010
Funding for routine operations and maintenance		
Retention of trained staff		
Interest for Plant Genetic Resource Conservation by donors		
Genetic variability in the collection as needed by users/breeders		
Access to germplasm information (passport, charact., evaluation)		
Active support/feedback by users		
Level of use by breeders		
Other factors (please specify):		

7.10 Please indicate the expected situation in 2010 of the strawberry collection with respect to the following factors

	High/good	Adequate/ moderate	Not sufficient	Not applicable
7.10.1 Funding for routine operations and maintenance				
7.10.2 Retention of trained staff				
7.10.3 Interest for Plant Genetic Resource conservation by donors				
7.10.4 Genetic variability in the collection as needed by users/breeders				
7.10.5 Access to germplasm information				
7.10.6 Active support/feedback from users				
7.10.7 Level of use by breeders				
7.10.8 other factors (specify below)				

8. Safety duplications in other institutions

(Safety duplication: defined as the storage of a duplicate/copy of an accession in another location for safety back-up in case of loss of the original accession.)

8.1 Are strawberry accessions safety-duplicated in another genebank? ☐ YES ☐ NO

8.1.1 If YES, please specify in the table:

Name of institute maintaining your safety duplicates:	Number of accessions	Storage conditions (short, medium, long term)	Nature of the storage (e.g. black box, fully integrated in host collection, etc.)
1.			
2.			
3.			
4.			
5.			
6.			
7.			

9. Institutions storing safety duplicates of strawberry in your genebank

9.1 Is there any strawberry germplasm of other collections safety-duplicated at your facilities?

☐ YES ☐ NO

9.1.1 If YES, please specify in the table:

Name of holder of the original collection:	Number of accessions	Storage conditions (short, medium, long term)	Nature of the storage (e.g. black box, fully integrated in host collection, etc.)
1.			
2.			
3.			
4.			
5.			

10. Further issues on duplication of strawberry collection

10.1 To what extent do you consider the strawberry accessions in your collection to be unique and not duplicated extensively elsewhere (i.e. EXCLUDING safety-duplication)?

☐ Fully unique
☐ Mostly unique
☐ Partially unique
☐ Fully duplicated elsewhere

10.2 Are there any constraints to duplicating the strawberry collection elsewhere outside your country? ☐ YES ☐ NO

10.2.1 If YES, please specify: _____

11. Institutions storing safety duplicates of strawberry in your genebank

11.1 Please enter the name of the institute maintaining the original strawberry collection and then the number of accessions tat are safety-duplicated at your genebank in brackets:

Example:
Institute 1: National Clonal Germplasm Repository Corvallis (25)
Institute 2 Centro de Investigacion y Formacion Agroalimentaria, Malaga, Spain (30)

Institute
1
2
3
4
5

11.2. Storage conditions:

Institute 1	**short**	**medium**	**long term**
Institute 2	**short**	**medium**	**long term**
Institute 3	**short**	**medium**	**long term**
Institute 4	**short**	**medium**	**long term**
Institute 5	**short**	**medium**	**long term**

11.3 Nature of the storage (e.g., black box, fully integrated in host collection)

Institute 1
Institute 2
Institute 3
Institute 4
Institute 5

12. Further issues on duplication of strawberry collection

12.1 To what extent do you consider the strawberry accessions in your collection to be unique and not duplicated extensively elsewhere (excluding safety duplication)?

Fully unique
Mostly unique
Partially unique
Fully duplicated elsewhere

12.2 Are there any constraints for duplication of the strawberry collection elsewhere outside your country?
Yes No
If "No" please specify:

13. Information management

13.1 Do you use an electronic information system for managing the strawberry collection (data related to storage, germination, distribution, etc.)? ☐ YES ☐ partly ☐ NO

13.1.1 If YES, what software is used? _____

13.2 Please indicate the proportion (%) of the following types of data is: (1) documented and (2) the proportion that is available electronically:

13.3 to 13.5

Type of strawberry germplasm	**Passport data**		**Characterization data**		**Evaluation data**	
	Doc.	**Electr.**	**Doc.**	**Electr.**	**Doc.**	**Electr.**
Wild related species	%	%	%	%	%	%
Landraces	%	%	%	%	%	%
Obsolete improved cultivars	%	%	%	%	%	%
Advanced improved cultivars	%	%	%	%	%	%
Breeding/research materials	%	%	%	%	%	%
Inter-specific derivatives	%	%	%	%	%	%
Unknown	%	%	%	%	%	%
Other, specify:	%	%	%	%	%	%

13.6 In case the information on the strawberry collection is not computerised, are there plans to do so in the future?

☐ No plans
☐ Computerisation planned within 3 years
☐ Other

13.7 Is information of the strawberry collection accessible through the Internet?

☐ YES ☐ partly ☐ NO

13.7.1 If there is NO data available in the internet, do you produce a printed catalogue?

☐ YES ☐ NO

13.7.1.1 If YES, would you be able to provide the Trust with a copy? ☐ YES ☐ NO
If YES, please include a copy to Dr Kim Hummer (*khummer@ars-grin.gov*), when returning the completed questionnaire!

13.8 Are data of the strawberry collection included in other databases?

National	☐ YES	☐ partly	☐ NO
Regional	☐ YES	☐ partly	☐ NO
International	☐ YES	☐ partly	☐ NO

13.8.1 If YES or partly, indicate the database (e.g. GRIN, SINGER, EURISCO etc.):

_____

14. Distribution and use of material

14.1 What proportion (%) of the total strawberry collection is AVAILABLE for the following distributions? Nationally: _____% Regionally: _____% Internationally: _____%

14.2 Please fill in the number of strawberry accessions DISTRIBUTED annually, and indicate the expected change over the next 3-5 years, where: + = increasing, 0 = no change, - = decrease

	Number of accessions distributed annually (average of last 3 years)	**Expected change for the next 3-5 years**
Nationally		
Regionally		
Internationally		

14.3 Do you put specific conditions or requirements for distribution of strawberry accessions?

☐ YES ☐ NO

14.3.1 If YES, please specify: _____

14.4 What is the proportion of strawberry germplasm sufficiently available in terms of QUANTITY for distribution?

Type of materials	**% of accessions sufficiently available**
Seeds:	
In vitro material:	
Cryopreserved material:	
Other, please specify:	

14.5 Is the distribution of strawberry germplasm available in terms of its HEALTH status?

- Seeds: ☐ YES ☐ partly ☐ NO
- *In vitro* material: ☐ YES ☐ partly ☐ NO
- Cryopreserved material: ☐ YES ☐ partly ☐ NO
- Other, please specify:(_____ _____) ☐ YES ☐ partly ☐ NO

14.6 Do you have adequate procedures in place for...

…Phytosanitary certification? ☐ YES ☐ NO

…Packaging? ☐ YES ☐ NO

…Shipping? ☐ YES ☐ NO

…Other, please specify: (_____) ☐ YES ☐ NO

14.7 Do you keep records of the strawberry accession distribution?

(e.g. who received it, quantity, date of shipment, nature of distributed material etc.)

☐ YES ☐ NO

14.8 Please indicate the proportion (in %) of users who received strawberry germplasm from you in the past 3 years:

Type of users:	Proportion of total distribution %
Farmers and Farmers' organisations	
Other genebank curators	
Academic Researchers and Students	
Domestic users	
Foreign users	
Plant breeders - public sector	
Plant breeders - private sector	
NGOs	
Others, please specify:	

14.9 Describe briefly how you inform potential users about the availability of strawberry accessions and their respective data in your collection?

_____
_____
_____

14.10 Describe briefly what are the most important factors limiting the use of the strawberry material maintained in your collection?

_____
_____
_____

14.11 Indicate if users have to pay money or not when they request material from you:

for accessions: ☐ free ☐ cost (in US$/accession): _____
for the **shipment**: ☐ free ☐ cost (in US$/accession): _____

14.12 Do you use a <u>Material Transfer Agreement</u> when distributing material?

☐ YES ☐ NO

14.13 Do you have any restrictions on who can receive strawberry materials?

☐ YES ☐ NO

14.13.1 If YES, please specify: _____

<u>15. Networks of strawberry genetic resources</u>

15.1 Do you collaborate in (a) network(s) as a strawberry collection holder?

☐ YES ☐ NO

15.2 If you collaborate in (a) network(s) please provide the following information of them:
*(**A**) name, (**B**) type (national, regional or worldwide), (**C**) main objectives, and (**D**) a brief description of the main reasons to participate in the network.*

A Name of network	B Type of network National/Regional/Worldwide	C Main objectives of the network	D Brief description of the main reasons to participate in the network

16. Major constraints

Please list the 5 major limitations you are facing in the management of the strawberry collection:

1. _____
2. _____
3. _____
4. _____
5. _____

17. Additional crop collections maintained in your institute

Please provide requested information of other crop collections (besides strawberry) managed in your institute in the space below

	Crop or species	Number of accessions	% of wild relative species
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

18. Question concerning institutes NOT maintaining strawberry *ex situ* collections

18.1 If your institute does not maintain an *ex situ* collection of strawberry, please indicate the following, to the best of your knowledge:

Current strawberry conservation activities in your institute:	
Institute focal person to contact for further details:	
Plans for any strawberry *ex situ* conservation:	
Any other information:	

19. Please add any further comments you may have:

_____
_____
_____
_____

Thank you for your important contribution!!!

Please return this questionnaire, **no later than April 21, 2006**, to:

Dr Kim Hummer, Research Leader
USDA Agricultural Research Service (ARS)
National Clonal Germplasm Repository (NCGR)
33447 Peoria Road, Corvallis, Oregon 97333, USA
Tel: 541.738.4201, fax: 541.738.4205,
Email: khummer@ars-grin.gov

Annex 6. Strawberry collection managers that responded

	Collection/ Country	Contact name and address	Type of Institution	Financing Body	Under IT?	Legal Owner
Latin America						
1	Argentina, Tucuman	Marta Eugenia Arias, Sergio Miguel Salazar Av. Independencia 1900, Junin 1049 San Miguel de Tucuman, Argentina arias@csnat.unt.edu.ar Ing. Agr. Daniel S. Kirschbaum, Ph.D. Coordinador Area de Investigacion EEA INTA Famaillá Ruta Prov. 301, Km 32, Famailla (4132) Tucuman, Argentina Tel. 54-3863-461048 x 9147 dkirschb@correo.inta.gov.ar www.inta.gov.ar/famailla/frutilla	University	INTA/ University	YES	YES
2	Brazil, Campinas	Instituto Agronomico de Campinas Campinas, Brazil	Govern-mental	Instituto Agronomico de Campinas	YES	YES
3	Chile, Santiago	GAMBARDELLA MARINA santa Rosa 11315, La Pintana Santiago agronomia.uchile.cl	University	University of Chile	NO	YES
4	Chile, Talca	Peter D.S. Caligari, Basilio Carrasco Dr. Jorge B. Retamales Depto. Horticultura Universidad de Talca Fax: 56 71 200212 Phone 56 71 200214 jretamal@utalca.cl	University	University of Talca	YES	YES
Europe						
5	Belgium, Meise	Ir. Dirk De Meyer National Botanic Garden of Belgium Domain of Bouchout B-1860 Meise, Belgium	Private, Botanic Garden	National Botanic Garden of Belgium	YES	YES
6	Czech Republic, Holovousy, Horice	Ing. Frantisek Paprstein, CSc. Research and Breeding Institute of Pomology Holovousy 1 508 01 Hořice v Podkrkonoší Czech Republic tel.: +420 493 691066 +420 603 225635 fax: +420 493 692833 e-mail: fp@vsuo.cz	Private	Research Institute of Pomology	YES	YES
7	Denmark, Tasrup	Torben Toldam-Andersen The Royal Vet. and Agric. University Department of Agricultural Sciences Crop science Højbakkegård Allé 21 DK- 2630 Taastrup, Denmark Phone: +45 3528 3411 Fax: +45 3528 3478 Email: tbta@kvl.dk www.kvl.dk	University	Royal Veterinary and Agricultural University	YES	YES
8	Finland, Piikkio	Tarja Hietaranta MTT Agrifood Research Finland, Plant Production Research, Horticulture, Toivonlinnantie 518 Piikki" FI-21500 Finland Tel: +358 2 477 2202 Fax: +358 2 477 2299 tarja.hietaranta@mtt.fi	Govern-mental	MTT	YES	YES

		www.mtt.fi				
9	France, Bellegarde	Laurence Bourrain CTIFL Centre de Balandran 30 127 Bellegarde Tel : 04 66 01 10 54 Fax : 04 66 01 62 28 Bourrain@ctifl.fr www.fruits-et-legumes.net	Govern-mental	CTIFL, Centre de Baladran	NO	YES
10	France, Douville	Philippe Chartier Responsable programme Création Variétale CIREF Maison Jeannette 24 140 Douville philippe.chartier@ciref.fr Tél : 05-53-80-39-33 Port: 06-72-91-19-02 Fax : 05-53-80-89-50				
11	Germany, Dresden	Dr. Monika Höfer Bundesanstalt für Züchtungsforschung an Kulturpflanzen Institut für Obstzüchtung Pillnitzer Platz 3a 01326 Dresden, Germany Tel. +49-351-2616222 Fax: +49-351-2616213 e-mail m.hoefer@bafz.de http://www.bafz.de	Govern-mental	Federal Centre for Breeding Research on Cultivated plants, Institute of Fruit Breeding	YES	YES
12	Germany, Stuttgart	Lothar Schatz, Sonja Merkle Reinhold Hummel GmbH+Co.KG, Koestlinstr. 121 Stuttgart, Germany schatz@hummel-erdbeeren.de www.hummel-erdbeeren.de	Private	Hummel- *In vitro*	NO	YES
13	Italy, Forli	Dr. Walther Faedi Direttore CRA - ISFR-FO Via La Canapona, 1 bis Magliano c.p. 7178 47100 Forlì (FC) - ITALY tel ++39 0543 89428/89492/89566 fax ++39 0543 89077 cell 349 2282055 e-mail: faedi.isf@agraria.it walther.faedi@entecra.it http: www.agraria.it/isf	Govern-mental	Instituto Sperimentale per la Frutticoltura Sezione di Forli	YES	YES
14	Netherlands, Tiel	Marcel Kers Croppings Dulker 5 4007 RP Tiel, The Netherlands Tel: +31 653 375 092 Fax +31 344 635 083	Private	Croppings	NO	YES
15	Norway, Aas	Arnfinn Nes Bioforsk Øst Kise Norwegian Institute for Agricultural and Environmental Research Kiseveien 337 2350 Nes på Hedmark NORWAY Tel: 40 62 26 21 Arnfinn.nes@bioforsk.no	University	Norwegian University of Life Sciences	YES	YES
16	Poland, Warszawa,	janusz@sadpol.com www.sadpol.com	Private	Sadpol	NO	NO

17	Romania, Pitesti	Coman Mihai Research Institute For Fruit Growing, Marului Street , No. 402 Pitesti - Maracineni, Romania icpp_mar@geostar.ro www.icdp-m.com	Govern-mental	Research Station for Fruit Growing, Cluj	NO	YES
18	Spain, Malaga	J. F. Sanchez-Sevilla, CIFA-Malaga Andalusian Institute of Fishery and Agrarian Research and Biological Agriculture (IFAPA) Malaga, Spain	Govern-mental	CIFA IFAPA	YES	YES
19	UK, England	Dr. David Simpson East Malling Research New Road, East Malling. Kent, UK Direct line: +44 1732 523744 Fax: +44 1732 849067 Website: www.emr.ac.uk	Govern-mental	East Malling Research Station	YES	YES
20	UK, KEW	Paul Smith, Janet Terry Millenium Seed Bank, RBG Kew Ardingly P.Smith@rbgkew.org.uk www.rbgkew.org.uk	Govern-mental	Royal Botanical Gardens, KEW	YES	YES
21	UK, Scotland	Dr. Rex M. Brennan Fruit Breeding Group Scottish Crop Research Institute Invergowrie, Dundee DD2 5DA, Scotland, UK Tel. +44 (0)1382 562731 (switchboard) 560001 (direct) Fax. +44 (0)1382 562426 Websites: www.fruitgateway.co.uk www.scri.ac.uk	Govern-mental	SCRI	YES	YES
22	VIR Russia	Yury Sokolov, Leonid Burmistrov N.I. Vavilov All-Russian Res. Inst. of Plant Industry (VIR), Bolshaya Morskaya st., 42St-Petersburg, Russian Federation l.burmistrov@vir.nw.ru http://www.vir.nw.ru/	Govern-mental	VIR	YES	YES
North America						
23	Canada, Agassiz	Chaim Kempler Agriculture and Agri-Food Canada P.O. Box 1000, 6947 #7 Highway Agassiz, B.C. http://res2.agr.gc.ca/parc-crapac/agassiz/progs/crop_science/kempler_e.htm kemplerc@agr.gc.ca	Govern-mental	Agriculture and Agri-Food Canada	NO	YES
24	Canada, Harrow	Margie Luffman Curator/Conservatrice Canadian Clonal Genebank/ Banque canadienne de Clones Agriculture and Agri-Food Canada/ Agriculture et Agroalimentaire Canada Telephone/Téléphone: 519-738-2251 ext. 474 Facsimile/Télécopieur: 519-738-2929 2585 County Road 20 Harrow, Ontario N0R 1G0 luffmanm@agr.gc.ca	Govern-mental	Agriculture and Agri-Food Canada	YES	YES
25	Canada, St. Etienne des	Frederick Laforge Phytoclone	Private	Phytoclone	NO	NO

	Gres	1943 Principale St-Etienne-Des-Gres, Canada				
26	United States, Corvallis	Kim E. Hummer USDA ARS National Clonal Germplasm Repository 33447 Peoria Road Corvallis, Oregon, United States Tel: 541.738.4201 Fax: 541.738.4205 khummer@ars-grin.gov http://www.ars.usda.gov/main/site_main.htm?modecode=53-58-15-00	Govern-mental	US Dept of Agriculture	YES	YES
27	United States, Colorado	Dr. Dave Ellis Lead Scientist, Curator Plant Genetic Resources Preservation Program National Center for Genetic Resources Preservation 1111 South Mason Street Fort Collins, CO 80526 USA telephone - 970 495 3227 fax - 970 221 1427	Govern-mental	US Dept of Agriculture	YES	YES
Asia						
28	Korea, Busan	Rho Il-Rae Protected Horticulture Experiment Station, 20-5, Gang-Dong Dong, Gang-seo, Busan 618-800 Korea Tel: 82-051-602-2121 Fax: 82-051-971-2024 lrno12@rda.go.kr http://www.nhri.go.kr/greenhouse/	Govern-mental	Protected Horticulture Experiment Station	NO	?
29	Korea, Suwon	Daeyoung Kim Vegetable Division, NHRI (National Horticultural Research Institute) 475, IMok-Dong, JangAn-Gu Suwon, KyongGi-Do, 440-706 Rep. of Korea Tel : 82-31-240-3582 Fax : 82-31-240-3594 Email : young78@rda.go.kr	Govern-mental	RDA	NO	YES
30	Japan, Kagawa	Dr. Tomohiro, Yanagi Faculty of Agriculture, Kagawa University, Ikenobe 2393, Miki-cho, Kita yanagi@ag.kagawa-u.ac.jp http://www.ag.kagawa-u.ac.jp/english/index.html	University	Kagawa University	No	Not in UPOV
31	Japan, Kurume		Govern-mental	KONARC/NARO	YES	YES
32	Japan, Morioka	Kiyoshi Okamoto National Agriculture Research Center for Tohoku Region (NARCT) JAPAN 92 Nabeyashiki, Shimokuriyagawa, Morioka 020-0123 JAPAN Tel:019-641-9204 Fax:019-641-6315 Email: z691ko@affrc.go.jp http://tohoku.naro.affrc.go.jp	Govern-mental	NARO AFFRC	YES	YES
Middle East and Africa						
33	Afghanistan	Rupert Knowles, County Director Global Partnership for Afghanistan (GPFA) Wazir Akbar Khan, Street 13/2 House 508 Kabul, Afghanistan	Private, NGO	Global Partnership for Afghanistan		

		Rknowles@gpfa.org www.gpfa.org				
34	Israel, Ness Ziona	Shamay Izhar Fertiseeds Ltd., B-A Science Park, Kiryat Weizmann. PO Box 4003 Ness Ziona, Israel	Private	Fertiseeds	YES	YES
	Morocco	Phillipe Mathys Diramar Route de Rabat Km 15 Laouamra, Maroc Tel: 221 39900881				
35	Turkey	Sevgi Paydas, Sedat Serŧe Cukurova University, Agricultural Faculty, Horticulture Department Adana, Turkey sevpay@cu.edu.tr http://ziraat.cu.edu.tr/bolumler/bahce/index_en.htm	University	Cukurova University	YES	YES
Oceania						
36	Australia, Nambour	Mark Herrington Principal Horticulturist (Breeding) Department of Primary Industries and Fisheries Horticulture and Forestry Science Maroochy Research Station PO Box 5083 SCMC NAMBOUR QLD 4560 AUSTRALIA Telephone 07 5444 9637 Facsimile 07 5441 2235 Email mark.herrington@dpi.qld.gov.au Website www.dpi.qld.gov.au Call Centre 132523	Govern-mental	Department of Primary Industries and Fisheries, Horticulture and Forestry Science, Maroochy Research Station, SCMC		YES
37	New Zealand, Aukland	A. Perich RD 3 Albany Auckland, New Zealand	Private		NO	YES

Annex 7. Other known strawberry genebanks that did not respond

	Collection Country	Contact name and address	Type of Inst.	Financing Body	Subject to IT
1	Belgium	Philip Lieten Filip.lieten@proeftuin.be	Gov.	Res. Inst	YES
2	Bulgaria, Kostinbrod	Violeta Savova Kondakova Agrobioinstitute, Ministry of Agriculture Violeta83@hotmail.com	Gov.	Min. of Ag.	YES
3	China, Beijing	Chinese Academy of Agricultural Sciences Baishiqiao Road 30, Beijing 100081 tel: (+86) 10-68919474 fax: (+86) 10-62174060 caas@net.cn	Gov.	CAAS	?
4	China, Jilin	Pomological Institute Jilin Agricultural Academy Gong-zu-ling, Jilin Province	Gov	Jilin Ag. Acad.	?
5	Estonia	Poli Horticultural Institute PO Karksi Nuia Viljandimaa 69104, Estonia Tel: (+372) 43-31443 (+372) 43-31442 toivo@pai.neti.ee	Gov	Poli Hort. Inst.	YES
6	Former Yugoslavia Macedonia	Victor Gamovski Agriculture Institute, Skopje, Rep. Macedonia vgamo@yahoo.com	Gov	Agri. Inst.	YES
7	Hungary, Fertod	Ferenc Dénes Research Institute for Fruit Growing, Fertőd, Hungary fkut@axelero.hu	Gov	Res. Inst. for fruit growing	YES
8	India, Shimla	Regional Station National Bureau of Plant Genetic Resources (NBPGR) Phagli, Shimla 171021 India	Gov	NBPGR	
9	Lithuania, Babtai	Rytis Rugienius Lithuanian Institute of Horticulture, LT-54333 Babtai, Kaunas District, Lithuania r.rugienius@lsdi.lt, http://www.lsdi.lt	Gov	Inst. of Hort.	YES
10	Netherlands, Wageningen	Plant Research International, Wageningen University and Res. Cen. Website: http://www.wur.nl	Gov	Univ.	YES
11	Poland, Skierniewice	Edward Zurawicz Research Institute of Pomology and Floriculture, Skierniewice E.Zurawicz@insad.pl	Gov	Inst. of Pom. and Flor.	YES
12	South Africa		Gov.		YES
13	Sweden, Balsgard	Viktor Trajkovski Nordic Genebank, Alnarp viktor.trajkovski@telia.com, http://www.ngb.se	Gov	Nordic Genebank	YES
14	Switzerland	André Ançay Swiss Federal Agricultural Research Station Changing Centre for Fruit-Growing and Horticulture of Fougères CH-1964 Conthey, Switzerland andre.ancay@rac.admin.ch www.racchangins.ch	Gov	Fed. Agri. Res. Sta.	YES

Annex 8. Composition and size of responding genebanks and collections

Germplasm Collection	Coll. Type [z]	Total num.	F. chil.	F. ves.	F. vir.	F. x ana.	Other spp.	Land-race	Old cvs	Adv. lines / breed.	Oth. Cult.
Afghanistan	R	3	0	0	0	3	0	0	0	0	0
Argentina	B	38	2	1	2	18	15	0	0	0	0
Australia	B	10	0	0	0	10	0	0	0	0	0
Belgium	R	2	0	1	0	1	0	0	0	0	0
Brazil	B	160	0	0	0	160	0	0	0	0	0
Canada, Agassiz	B	692	10	2	0	0	0	0	30	600	50
Canada, Etienne de Gris	B	200	0	0	0	0	0	0	10	190	0
Canada, Harrow,	G, B	1782	818	26	175	636	2	0	0	125	0
Chile, Santiago	B	129	113	0	0	16	0	0	50	16	0
Chile, Talca	B	551	214	0	0	5	0	2	0	330	0
COST 836 (netwk)	G, B	1474	0	0	0	0	418	0	1056	0	0
Czech Republic	G	47	0	12	0	0	0	0	0	35	0
Denmark	G,R	185	1	4	1	0	7	0	172	0	0
Finland	G	38	0	1	0	0	14	0	13	10	0
France, Bellegard	G, B	186	0	2	2	0	0	0	132	50	0
France, Douville	G	101	0	0	0	101	0	0	0	0	0
Germany, Stuttgart	B	10	0	0	0	10	0	0	0	0	0
Germany, Dresden	G, B	660	8	41	14	109	121	9	335	0	23
Iran	R	17	0	0	0	17	0	0	0	0	0
Israel	G, B	312	0	0	0	0	0	0	306	6	0
Italy	G, B	60	1	1	0	0	1	0	15	42	0
Japan (Kagawa)	B	40	2	12	1	0	0	3	13	5	4
Japan (Kurume)	B	200	0	0	0	200	0	0	0	0	0
Japan (Morioka)	B	211	0	0	0	0	0	0	0	208	3
Korea, Busan	G, B	153	1	1	1	0	0	0	0	150	0
Korea, Suwon	B	130	1	0	0	0	0	0	0	129	0
Morocco	R	5	0	0	0	5	0	0	0	0	0
Netherlands	B,R	10	0	0	0	10	0	0	0	0	0
New Zealand	R	10	0	0	0	10	0	0	0	0	0
Poland, Warszawa	B	0	0	0	0	0	0	0	0	0	0
Romania	G. B	247	1	3	0	132	4	0	25	68	14
Russian Fed.	G	1210	17	16	17	0	115	30	60	932	23
Spain, Malaga	G, B	660	0	0	0	0	103	0	247	319	0
Turkey	G, B	86	12	35	18	4	5	0	0	12	0
UK East Malling	B	343	16	12	4	0	9	0	60	242	0
UK Scotland	B	20	0	0	0	20	0	0	0	0	0
UK, Kew	G	16	2	14	0	0	0	0	0	0	0
US, Corvallis, OR	G	1924	442	139	435	0	121	2	200	400	185
US, Ft. Collins, CO	G	199	3	16	39	27	16	0	98	0	0
Total		**12121**	**1664**	**339**	**709**	**1494**	**951**	**46**	**2822**	**3869**	**302**

[z] G = genebank; B = breeding; R = research

Annex 9. Aspects of each strawberrry genebank that responded

Genebank	
Belgium	Older European cultivars and indigenous European species
Canada, Harrow, Ontario	Fairly large collection of Canadian indigenous germplasm that is cold hardy and drought resistant, some disease resistant material
Chile, Talca	Large collection of Chilean indigenous germplasm that has good fruit quality, range of tolerance to salt, cold Botrytis; selection for aroma, taste color, tolerance to biotic and abiotic stresses.
COST 836 (network)	Older European cultivars and indigenous European species
Czech Republic	Preservation of biodiversity of domestic cultivars, Suitability of used cultivars for climatic conditions of the Czech Republic
Denmark	The relative high number of old/historical cultivars. We have in some cases send old cultivars back to different places in Europe. There is quite a large variation in the fruit characteristics in the collection but I think the main interest is for those interested in the historical aspects. Some selections however are from Nordic/Danish breeding in 1970-1980 connected to development of mechanical harvest. Some of these selections have interesting agronomical characters (position of fruit in the canopy, ease of harvest, homogen ripening, good colour and sugar/acid for industrial use etc.)
Finland	Material is adapted to our Northern conditions. Winter hardiness
France, Bellegard	We preserve part of the cultivars which are produced in France
France, Douville	Older European cultivars and those of interest to France
Germany	Size and diversity of the collection, older German cultivars and indigenous European species are represented. Moderate representation of east Asian species.
Israel	Early yielding cultivars. Mainly of the infra short day strawberry type. For earliness and fruit quality.
Italy	Many genotypes of different origins are adapted to different climatic conditions and are growing in the same field located in Rome. It is possible to make evaluation about their disease susceptibility. The main importance is to use genotypes for crossing to improve disease resistance, fruit size fruit quality including flavour and taste.
Korea, Busan	We are interesting to large fruit, high sugar, high yield, and diease resistance. We are also interested in inbred lines in strawberry cultivars. We want to breed of domestic cultivars because the majority of strawberries cultatived at our country are foreign.
Romania	We have the responsibility preserve 2 cultivars that are included in European Core Collection. We also preserve old European cultivars for traits such as:flavour and resistance, and new cultivars for fruit size and firmness.
Russian Federation	Representation of world strawberry gene pool including old domestic and foreign cultivars.
Spain	Older Spanish cultivars and European species are represented
Turkey	We preserve genotypes that have been selected from seedlings growing in Turkey. Although Turkey is not center of origin for strawberry, growers selected genotypes for their aroma.Other aspects are being currently evaluated.
UK, Kew	Millenium seed genebank
UK, East Malling	Biggest collection in UK, but not unique
US, CO	Remote back-up location for the working genebank in Corvallis.
US, Corvallis	Large representation of indigenous American *F. chiloensis, F. virginiana* accessions. Moderate representation of east Asian species Moderate representation of older American heritage strawberries Moderate representation of newer strawberry cultivars

Annex 10. Recent acquisitions

Supporting Countries	Exploration Locality	Year	Species collected
USDA-Chile	Chile	1990	*F. chiloensis* subsp. *patigonica* *F. c. subsp. c.* forma *chiloensis*
USDA-Chile	Chile	1992	*F. chiloensis* subsp. *patigonica* *F. c.* subsp. *c.* forma *chiloensis*
USDA	Mid-western United States	1995	*F. virginiana*, *F. vesca*
AAFC	Quebec	1994	*F. virginiana*
USDA	Southeastern United States	1995, 1996, 2000	*F. virginiana* *F. vesca*
USDA	Alaska	1996	*F. chiloensis* subsp. *pacifica* *F. virginiana* subsp. *platypetala*
	Europe: Germany	1996	*F. vesca, F. viridis, F. moschata*
USDA-Bulgaria	Bulgaria	1996	*F. vesca*
USDA-Russian Federation	Primorye, Khabarovsk, Amur, Sakhalin	2001, 2003, 2004, 2005	*F. orientalis* *F. nipponica* *F. iturupensis*, F. hybrids
USDA-Japan	Hokkaido	2004	*F. nipponica, F. iinumae*, hybrids
USDA	Southeastern and mid-western United States	2007	*F. virginiana* subsp. *virginiana*, *F. v.* subsp. *grayana*

Annex 11. Gaps in the collections of genebanks that responded

Genebank	
Belgium	
Canada, Harrow, Ontario	Yes, ecological repesentation of the species
Chile, Talca	Yes, in Northern and Southern Andes locations from Chile
COST 836 (network)	
Czech Republic	No gaps
Denmark	No information
Finland	No information
France, Bellegard	No information
France, Douville	Yes, cultivars of *F. moschata*
Germany	Yes, species coverage
Israel	Yes, species coverage
Italy	Yes, species coverage
Korea, Busan	No information
Romania	YES, species coverage, population sample representatives of the species, ecological repesentation of the species
Russian Federation	Yes in population sample representatives of the species
Spain	
Turkey	YES, species coverage, population sample representatives of the species, ecological repesentation of the species
UK, Kew	No gaps
UK, East Malling	Yes, insufficient population sample representation per species, insufficient ecological representation of the species.
US, OR	YES, species coverage, population sample representatives of the species, ecological repesentation of the species
US, CO	NA

Annex 12. Identification and characterization of major collections

Genebank	Taxonomic classification	Database	Descriptor list (type)	% collection characterised
Belgium	Yes	COST	IPGRI, COST	?
Canada, Harrow, ON	Yes	GRIN-CA Access	IPGRI	100% species
Chile, Talca	Yes	Excel	In house	5-50%
COST 836 (network)	Yes	COST	IPGRI, COST	25%
Czech Republic	Yes	EVIGEZ ISGOOD Eurisco	IPGRI, COST	100%
Denmark	Yes	Nordic Genebank	In house	20%
Finland	Yes	Nordic Genebank	In house	?
France, Bellegard	Yes	COST Excel	IPGRI, COST	No information
France, Douville	Yes	COST Excel	IPGRI, COST	
Germany	Yes	COST Excel	IPGRI, COST	39-50%
Israel	Yes			
Italy	Yes	COST Excel	IPGRI, COST	20%
Korea, Busan	Yes	Not computerized	none	13-87%
Romania	Yes	COST Excel	IPGRI, COST	Planned within 3 years
Russian Federation	Yes	EURISCO. Paradox	inhouse	50-90%
Spain	Yes	COST	IPGRI, COST	In progress
Turkey	Yes	Excel	In house	100%
UK, Kew	Yes	Kew records	NA	NA
UK, East Malling	Yes	MS Access	IPGRICOST	?
United States, Corvallis, Oregon	Yes	GRIN, Foxpro Excel	GRIN, IPGRI	10%
US, CO	Yes (Corvallis)	GRIN	GRIN	NA

Annex 13. Storage methods and conditions

Collection/ Country	Primary plant storage conditions	Secondary plant storage conditions	Cryogenics	Seed storage conditions	DNA marker analysis
Belgium	Greenhouse	NO	NO	NO	BO
Canada, Harrow, Ontario	Inclosed shadehouse 5 C in winter, 24 C in summer	Screenhouses 5C in winter, 24 C in summer Ambient RH Also *in vitro*	NO	NO	NO
Chile, Talca	Covered open air nursery Ambient air temp. in pots	*In vitro* In culture jars	NO	YES	YES
COST 836 (network)	Multiple systems	Inter-country back-up			YES EST , SSR, AFLP
Czech Republic	Field collection	*In vitro*, 22 C Erlenmeyer flask	Meristems -196C dewars	NO	NO
Denmark	Field collection	NO	NO	NO	NO
Finland	Field collection	NO	NO	NO	NO
France, Bellegard	NO	*In vitro* Test tube, 1 C	NO	NO	NO
France, Douville	Stored in insect-proof tunnels and containers with fumigated sand	cleaned annually series by series by meristem culture			
Germany	Field collection Window boxes	*In vitro* 4 C StarPak	Some. In development	4 C	NO
Israel					
Italy	Field collection	No	NO	NO	NO
Korea, Busan	Greenhouse 0-30 C 20 – 90%RH	Plastic covered house 0-30 C 20-90 %RH	NO	NO	NO
Romania	Field collection	*In vitro*			
Russian Federation	NA	NA	NA	-10C, 80%RH sealed aluminium bag	NO
Spain	In pots, 3 replicates	*In vitro*	In development	NO	YES EST , SSR AFLP
Turkey	Field collection	NO	NO	NO	NO
UK, Kew	NA	NA	NA	Glass storage jars with natural rubber seals; -20 C	NA
UK, East Malling	Poly tunnel, no environment control	NO	NO	NO	NA
US, Corvallis, OR	Screenhouse 2 gal. deep pots	*In vitro* 4 C StarPak system	Meristems -196 C dewar	-20 C; outer Alum. bag, w/ inner envelope	YES EST , SSR AFLP
US, CO	NA	Revolving TC back-up 5 C 84% RH StarPaks	LN2, -196 cryovials, Liquid phase – meristems	LN2 -175 C Polypropylene tubes, Vapor.	NA

Annex 14. Health of strawberry collections at genebanks

Collection/ Country	Type of disease testing	Capable of eradicating diseases	Assistance required to improve health status
Belgium			
Canada, Harrow, Ontario	Virus testing for 5 viruses, every 2 years on 270 accessions	YES	YES
Chile, Talca	NO	NO (limited)	YES
COST 836 (network)	Depends on institute	YES	NO
Czech Republic	ELISA tests, PCR	YES	NO
Denmark	Do not have quality control activities	NO	YES
Finland	NO	NO	YES
France, Bellegard	No information	?	?
France, Douville			
Germany	Visual controls by staff and by phytosanitary office of Saxony Agriculture Institute	Collection is not affected by diseases that can restrict distribution within Europe	NO
Israel	By PPQ	?	?
Italy	YES	YES	NO
Korea, Busan	No information	?	?
Romania	Visual, Elisa, PCR, artificial infections	YES	NO
Russian Federation	Seed tested according to ISTA when put into storage	Only a few accessions affected by diseases, Limited facilities for disease elimination	YES
Spain	Visual controls by staff and by phytosanitary office	Collection is not affected by diseases that can restrict distribution within Europe	NO
Turkey	NO	NO	YES
UK, Kew	YES	NO	NO
UK, E.Malling	Phytosanitary avail.	NO	NO
United States, Corvallis, Oregon	Biological indicators, ELISA, PCR for dsRNA	YES	NO
US, CO	NA	NA	NA

Annex 15. Distribution of strawberry collections (% of total distribution)

Collection/ Country	Average annual distribution	Domestic %	Foreign %	Public sector %	Private sector %	NGO's, farmers, etc. %
Belgium						
Canada, Harrow, Ontario	40	30	10	20	10	35
Chile, Talca	0 (expecting increase to 100 in 5 yr)	70	30	70		
COST 836 (network)						
Czech Republic	40	10	90	15	5	70
Denmark	7	10	90	90	5	5
Finland	No Information	0	0	0	0	0
France, Bellegard	No Information	0	0	0	0	0
France, Douville						
Germany	33	64	36	0	14	24
Israel						
Italy	5 (change to 20 in 5 yr)	0	30	10	10	40
Korea, Busan	10	100 (to 200 in 5 yr)	0 (to 20 in 5 yr)	80	0	20
Romania	72	62	10	20	0	0
Russian Federation	80	100	0	100	0	0
Spain	?					
Turkey	Do not distribute	0	0	0	0	0
UK, Kew						
UK, East Malling	15	5	10	50	50	0
US, Oregon	800	75	25	33	33	33
US, CO	Does not distribute	0	0	0	0	0

Annex 16. Accessibility of information on the internet

Collection/ Country	Accessibility of germplasm and conditions	Mode distribution	Average annual distribution 2003-06	Data available on own or other Internet site
Belgium				
Canada, Harrow, Ontario	Freely	Seed, *in vitro*	40	Partly
Chile, Talca	Restricted with MTA	Seeds, plants	0	No
COST 836 (network)				Partly, in publications
Czech Republic	Freely and MTA	*In vitro*	40	Partly
Denmark	Minor cost no MTA	Runners, plants	7	NO
Finland	No information	Runners, plants	No info	NO
France, Bellegard	No information	*In vitro*	No info	No information
France, Douville				
Germany	Free cost but restricted, some with MTA	Seeds, plants	33	Partly
Israel	Comm. Agreement	*In vitro*		No; have catalog, planned in 3 yr.
Italy	Freely, No MTA	Plants, plug plants (runners)	5	Partly, catalog available
Korea, Busan	No cost, restricted, with MTA available domestically	plants	10	NO; have printed catalog
Romania			72	
Russian Federation	Freely and MTA	seeds	80	Partly
Spain				
Turkey	Do not distribute	NA	Do not distribute	NO
UK, Kew	Freely and MTA	seeds		
UK, E. Malling	Free and MTA	Propagules as requested	15	NO
United States, Corvallis, Oregon	Freely, No MTA	Seeds, runners, plants, *in vitro* culture, leaves, DNA	800	YES
US, CO		NA	Do not distribute	YES

Annex 17. Safety duplication of strawberry collections

Collection/ Country	Organised	Place of duplication	Holding safety duplicates of other strawberry collections
Belgium	YES	COST	COST
Canada, Harrow, ON	Partly	AAFC Agassiz AAFC St. Etienne des Gres	A few for USA
Chile, Talca	NO	NO	NO
COST 836 (network)	YES	Within intercountry network	YES
Czech Republic	YES	Research Institute of Crop Production, Prague – Ruzyne	NO
Denmark	YES	No but member of Nordic Genebank	NO
Finland	YES	Nordic Genebank	NO
France, Bellegard	YES	No information	No information
France, Douville	YES	COST	COST
Germany	YES	COST and Germany Bundessortenamt: Fruit	COST
Israel	NO	Israeli Plant Breeders Rights office	NO
Italy	YES	COST	COST
Korea, Busan	NO	NO	Partly
Romania	YES	COST	COST
Russian Federation	YES	Maikop Exp. Station Polar Branch, Murmansk	NO
Spain	YES	COST	COST
Turkey	NO	NO	NO
UK, Kew	NO	NO	NO
UK, E. Malling	YES	COST	COST
United States, Corvallis, OR	YES	US Colorado	US Colorado A few for Canada
US, CO	YES	US Corvallis	US Corvallis

Annex 18. General management of strawberry germplasm[z]

Collection/ Country	Acqui-sition	Regene-ration	Characte-risation	Storage	Documen-tation	Health	Distri-bution	Safety duplication
Belgium	Y	Y	Y	Y	Y	N	N	Y
Canada, Harrow, ON	Y	Y	N	N	N	Y	N	N
Chile, Talca	Y	Y	Y	N	Y	N	N	N
COST 836 (network)	Y	Y	Y	Y	Y	N	N	Y
Czech Republic	Y	Y	Y	Y	Y	Y	Y	Y
Denmark	N	Y	Y	N	N	N	N	N
Finland	N	N	N	N	N	N	N	N
France, Bellegard	No info	-	-	-	-	-	-	-
France, Douville	Y	Y	Y	Y	Y	N	N	Y
Germany	Y	Y	Y	Y	Y	Y	Y	Y
Israel	N	N	N	N	N	Y	N	N
Italy	N	N	N	Y	N	Y	N	N
Korea, Busan	Y	Y	Y	Y	N	N	Y	N
Romania	Y	Y	Y	Y	N	N	N	N
Russian Federation	Y	Y	Y	Y	Y	Y	Y	Y
Spain	Y	Y	Y	Y	Y	N	N	Y
Turkey	N	N	Y	N	N	N	N	N
UK, Kew	Y	Y		Y	Y	Y	Y	
UK, E. Malling	None available	None avail.	None avail.	None avail.	None avail.	None avail.	None avail.	None avail.
US, OR	Y	Y	Y	Y	Y	Y	Y	Y
US, CO	NA	NA	NA	Y	Y	NA	NA	NA

[z]Yes means, the genebank stated to have written procedures or protocols for the listed genebank functions.

Annex 19. Resources available for strawberry genebanks

Collections (Country)	Coll. Size	Routine operations	Retention of staff	Interest in PGR	Genetic variability	Access to and use of collections	Active support from users	Level of use by breeders
Belgium	2							
Canada, Harrow, ON	1783	3	2	2	1	2	2	2
Chile, Talca	546	2	3	3	2	3	3	2
COST 836 (network)	1456							
Czech Republic	47	2	1	2	2	1	1	2
Denmark	185	2	2	NA	2	2-3	NA	3
Finland	38							
France, Bellegard	186	No response						
France, Douville	101							
Germany	660	2	2	1	1	2	1	1
Israel	312	3	3	3	2	2	3	2
Italy	60	2	2	NA	2	2	2	2
Korea, Busan	153	2	3	2	3	3	3	3
Romania	247	3	3	3	2	2	NA	2
Russian Fed.	1197	3	3	1	1	1	3	1
Spain	660							
Turkey	86	3	3	2	2	3	3	3
UK, Kew	16	No response						
UK, E. Malling	302	2	2	NA	2	2	1	1
US, OR	1924	3	3	2	1	1	1	1
US, CO	199	No response						
Total								

Ranking: 1= high/good, 2= adequate/moderate, 3= not sufficient/bad, NA

Annex 20. Major constraints of strawberry genebanks

Genebank	
Belgium	
Canada, Harrow, Ontario	No facilities to heat treat virus positive material. Virus titre is increasing with time. Other programs at same facility have totally different mandates; pests and diseases from these programs are easily transmitted to genebank material, other staff does not understand genebank program. Budget limitations re: hiring staff and students; administrative workload and other similar distractions; Department organization into national themes; management is not on-site or local so cannot appreciate certain inherent 'in-house' issues and problems
Chile, Talca	Man power, facilities for storage, Health status checking and remediation, finances for the above.
COST 836 (network)	Missing long term organisation in Europe (COST projects are insufficient). Missing actual information about collections in other countries. . Because of the above mentioned problems, problems of collections and exchange.
Czech Republic	Low availability of space, low availability of laboratory equipment, low sources of funding.
Denmark	The technical staff is there but I have very limited time to work with the collections. More scientific man hours are needed it this is to be more than basic keeping the collection. It is difficult to get external project funding which means no resources to develop and improve the collection. There is no breeding in the region to interact with.
Finland	None listed
France,Bellegard	None listed
France, Douville	Expect a loss of interest or of money and management to maintain clean genebank plants
Germany	Difficulties within COST regarding collections and exchange. Problems of preservation under field conditions. Problems of *in vitro* culture/cold storage and later cryo for many wild species.
Israel	No constraints. Small collection, will distribute on request for research
Italy	Sanitary problems, runner production, weeds
Korea, Busan	Difficult to distribute because of intellectual property rights issues (royalties). Have lost some genotypes that are not replaceable.
Romania	Support, no greenhouse available, perennial system of culture, bad irrigation source, weed infestation
Russian Federation	Insufficient funding for strawberry maintenance, limited possibilities for cleaning the genetic material, no adequate research personnel, no adequate equipment for field work, no adequate equipment for *in vitro* storage
Spain	
Turkey	Limited space, labor, funds, and resources, Pest and diseases are a problem.
UK, Kew	None listed
UK, E. Malling	Plant health, funding to maintain accessions
US, CO	Cryogenics is very labor intensive
US, Corvallis	Insufficient funding for strawberry maintenance, insufficient funding for pathogen testing

Annex 21. Sharing of facilities/expertise[z]

Collection/ Country	Con-serva-tion	Charac-terisa-tion	Safety duplic ation	Health Scree-ning	*In vitro*	Cryo-preser-vation	Distri-bution	Training in PGR manag	Docu-menta-tion
Belgium									
Canada, Harrow, Ontario	X	X			X		X	X	X
Chile, Talca									
COST 836 (network)									
Czech Republic	X	X	X	X			X	X	X
Denmark	X								
Finland									
France, Bellegard									
France, Douville									
Germany	X	X	X		X	X	X	X	X
Israel									
Italy					X				
Korea, Busan									
Romania									
Russian Federation	X							X	
Spain	X	X	X	X	X	X	X	X	X
Turkey									
UK, Kew	X						X	X	XX
UK, E. Mall.	X	X	X					X	
U S OR	X	X	X	X	X	X	X	X	X
US, CO	X		X		X	X		X	X

[z]X means that the genebanks offer facilities or expertise for the listed genebank functions. Conditions need to be further discussed with the respective genebanks

Annex 22. Solemn Undertaking to ensuring access as interim to ratifying the International Treaty for PGRFA

Solemn Undertaking (Access)

The Global Crop Diversity Trust is currently considering making a grant to the …(*institution*)… for upgrading the conservation and management of its …(*crop*)... collection of plant genetic resources for food and agriculture (PGRFA) to international standards. The …(*institution*)… hereby undertakes that, in the event that the grant is approved, the PGRFA covered by the grant that are of crops included in Annex I of the International Treaty on Plant Genetic Resources for Food and Agriculture (the International Treaty), will be made available for the purpose of utilization and conservation for research, breeding or training for food and agriculture in accordance with the terms and conditions set out in Part IV of the International Treaty. The award of any grant by the Global Crop Diversity Trust will be contingent upon the …(*institution*)… signing this Undertaking. This Undertaking will apply until such time as the host country becomes a Contracting Party to the International Treaty.

Signed ……. Title ……. on ……

(Authorized Person responsible for the ……institution)

I, being the Minister/Government Officer responsible for plant genetic resources for food and agriculture in …(*country*)…, hereby confirm that there are no legal obstacles to the …(*institution*)… fulfilling its undertaking as above.

Signed …… on ……..

Minister/Government Officer responsible for plant genetic resources for food and agriculture, …(*country*)…

Solemn Undertaking of commitment to the collection being maintained for long-term conservation

Solemn Undertaking (Conservation)

The Global Crop Diversity Trust is currently considering making a grant to the …(*institution*)… for upgrading the conservation and management of its …(*crop*)... collection of plant genetic resources for food and agriculture (PGRFA) to international standards. The …(*institution*)… hereby undertakes that, in the event that the grant is approved, the PGRFA covered by the grant that are of crops included in Annex I of the International Treaty on Plant Genetic Resources for Food and Agriculture (the International Treaty), will be conserved by the …(*institution*)… on a long term basis. The award of any grant by the Global Crop Diversity Trust will be contingent upon the …(*institution*)… signing this Undertaking.

Signed ……. Title …….. on ……

(Authorized Person responsible for the ……institution)