INRA National Institute of Agronomical Research

European strawberry and raspberry genetic resources - GENBERRY
AGRI GEN RES action 036

co-funded by the European Commission

under Council Regulation (EC) N° 870/2004¹

http://www.bordeaux.inra.fr/eustrawberrydb

1. Background

Horticultural crops have always played a vital role as fresh foods in the human diet. Some of them such as strawberries and raspberries are particularly interesting for consumers due to the special taste value and high content of health benefits, including dietary fibre, macro and microelements (K, P, Ca, Mg, Fe, Zn), and vitamins (A, B₁, B₂, B₆, PP, C, E) in the fruits. Annual world production of these berries amounts approximately 4.0-4.8 Mt with a total harvested area of over 300,000 ha.

In Europe, the total area devoted to berry cultivation covers approximately 190,000 ha (100,000 ha for strawberry, 30,000 ha for raspberry and 60,000 ha for other berries such as blueberry, gooseberry, currant, cranberry. Europe produces annually 1.1 Mt of strawberry and 0.14 Mt of raspberry.

Table 1. Countries with highest production of strawberry and raspberry in 2010 (based on FAO statistics). EU countries are marked with *.

<table>
<thead>
<tr>
<th>Country</th>
<th>Annual strawberry production in tones</th>
<th>Country</th>
<th>Annual raspberry production in tones</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>1,292,780</td>
<td>Russian Federation</td>
<td>125,000</td>
</tr>
<tr>
<td>Turkey</td>
<td>299,940</td>
<td>Poland *</td>
<td>87,556</td>
</tr>
<tr>
<td>Spain *</td>
<td>275,300</td>
<td>Serbia</td>
<td>83,870</td>
</tr>
<tr>
<td>Republic of Korea</td>
<td>231,803</td>
<td>USA</td>
<td>31,207</td>
</tr>
<tr>
<td>Mexico</td>
<td>226,657</td>
<td>Ukraine</td>
<td>25,700</td>
</tr>
<tr>
<td>Japan</td>
<td>177,500</td>
<td>Mexico</td>
<td>14,343</td>
</tr>
<tr>
<td>Poland *</td>
<td>176,748</td>
<td>Canada</td>
<td>11,864</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>165,000</td>
<td>Azerbaijan</td>
<td>10,100</td>
</tr>
<tr>
<td>Germany *</td>
<td>156,911</td>
<td>Spain *</td>
<td>10,000</td>
</tr>
<tr>
<td>Italy *</td>
<td>153,875</td>
<td>Bosnia and Herzegovina</td>
<td>7,937</td>
</tr>
</tbody>
</table>
In general, cultivation of strawberry and raspberry is largely extended in Europe, thanks to the plants high adaptability of to environmental conditions and improved growing techniques. However, despite the high adaptability of strawberry to environmental conditions, varieties are very specific to countries. For example, the varieties cultivated in Spain are very different to the ones cultivated in Sweden (see figures below).

1.1. The preservation of diversity of the cultivated strawberry and raspberry

Genetic resources are important for breeding programmes mainly because of 1) food security, 2) possible adaptation to changing environment (climate change) and 3) plant diseases resistance. It is therefore crucial to continue the effort of evaluation of varieties well adapted to the different European climates, Eastern, Western, Northern and Southern Europe. This effort should include also the new demand of consumers such as fruits with more flavour and with less or no fungicides and pesticides.

The project of GenBerry aimed to evaluate genetic resources that are representative of all available variability, including old strawberry cultivars for identifying the best varieties and genotypes. These varieties and genotypes represent potential parents for original traits (e.g. disease resistances, flavour, climate adaptability) and are consequently of great importance for breeding programmes.
Diversity in strawberry

**a. History of the common wild and cultivated strawberry, *Fragaria x ananassa***

Strawberry belongs to the genus *Fragaria* which displayed a polyploid series of wild species ranging from diploids (2n = 2x = 14) (two haploid genome) to decaploids (2n = 10x = 70) (10 haploid genomes). In addition to these wild species, the common cultivated octoploid species, *F. x ananassa* (2n = 8x = 56), was created only recently (about 250 years ago), which explain its narrow diversity compared to its widespread genitors. This species results from a hybridization by chance between two related octoploid species, North American origin scarlet strawberry (*F. virginiana* Mill.) and South American domesticated *F. chiloensis* (L.) Mill (please delete all scientific references). This hybridization occurred in a French botanical garden in the early 1700s, resulting in a new cultivated fruit species, *F. x ananassa*.

While diploid strawberry species such as the woody *F. vesca*, contains 14 chromosomes, the octoploid species are genetically complex since they contain four times the chromosome’s number of the diplo species.

Strawberry breeding began in England in the late 1700s, followed by France and Germany. The first selected European cultivars were used as genitors in early American breeding programmes, together with American native cultivars. Therefore, the origin of strawberry and these early breeding practices reduced initial genetic variability. During the around 200 years of strawberry breeding, initial diversity increased thanks to the use of wild strawberry germplasm or unrelated progenitors in breeding programmes which allowed to integrate new traits in varieties (introgression). However, the use of exotic germplasm was limited and therefore, the genetic diversity of the cultivated strawberry in modern strawberry cultivars is limited compare to its two relative wild American species.

In this context, it is of extreme importance to keep and breed all sources of wild and cultivated strawberries. The project was concerned with the conservation of the cultivated strawberry, and particularly varieties from Europe where breeding of strawberry has started.

**b. History of the cultivated raspberry, *Rubus idaeus***
*Rubus* is a member of the family *Rosaceae* and is one of the most diverse genera in the plant kingdom, comprising over 400 species subdivided into 12 subgenera. Ploidy levels range from diploid to 14-ploid.

The domesticated subgenera contain the raspberries, blackberries, arctic fruits and flowering raspberries, all of which have been utilised in breeding programmes. The most important raspberries are the European red raspberry, *R. idaeus* L. subsp. *idaeus*, the North American red raspberry *R. idaeus* subsp. *strigosus* Michx and the black raspberry (*R. occidentalis* L.). *Rubus* subgenus *Idaeobatus* is distributed principally in Asia but also East and South Africa, Europe and North America. There is another subgenus, *Eubatus*, which is mainly distributed in South America, Europe and North America.

Raspberries have always been attractive as fresh dessert fruits or for processing from frozen berries into conserves, purees and juices. In most European countries, USA bred cultivars have led the industry, such as ‘Meeker’, ‘Willamette’ and ‘Tulameen’. Primocane-fruiting cultivar ‘Heritage’ has led the industry in many countries. In Scandinavia, the hardy Norwegian variety ‘Veten’ has been the mainstay for many years, now ‘Glen Ample’ has taken the lead.

c. Collections of the cultivated strawberry and raspberry in Europe

Both strawberry and raspberry can be maintained in collections during several years. However, the turnover is much shorter for strawberry (2 years or even 1 year for some partners) than for raspberry (8 years).

Maintaining collections for several years can lead to sanitary problems such as Phytophthora (*Phytophthora rubi* for raspberry or *Verticillium dahliae* for strawberry).

Due to a large worldwide interest in strawberries and raspberries, numerous breeding programmes mainly in the Northern Hemisphere occurred in the past for strawberries and raspberries. In addition, strawberry fruits are produced in annual cultures, which leads to a relative quick turnover of the varieties. Therefore, a large number of varieties or genotypes of strawberries and raspberries exist.
1.2. Project objectives and activities

The first objective of the GENBERRY project was to continue maintaining the European genetic resources of cultivated strawberry and raspberry and to build the European small berries collections for strawberry and raspberry.

The second objective was to characterize the strawberry and raspberry collections using passport data and primary and secondary descriptors. The major descriptors were linked to health nutritional values such as vitamin C and plant disease resistances, e.g. *Phytophthora cactorum* and *Verticillium dahliae* resistances for strawberry and *Phytophthora fragaria var rubi*, *Botrytis cinerea* and *Didymella applanata* for raspberry. For strawberry, these descriptions were integrated in a European database. Characterization was also conducted using microsatellite markers for studying the genetic diversity of strawberry and raspberry. All descriptions of the strawberry including analyse of the genetic diversity was used for identifying the best possible core collection.

Preservation of agricultural biodiversity and characterization of this diversity will be of benefit to European breeding programmes as well as gardeners.

1.3 Maintaining collections

As the plants of the collections must be maintained vegetatively, some specific growing system must be used to keep them authentic and free of diseases such as insect proof tunnels or cryoconservation (conservation in -80°C). These growing systems are different for each partner according to their locations and the strawberry or raspberry species.

(i) Strawberry
For strawberry, collections can be maintained in open field in box systems or directly in field rows or under insect proof tunnel. The new plants are collected in winter as bare root plants and stored as frigo plants in cold rooms at -2°C.

Soilless systems, substrate type - peat, can be used to avoid some diseases such as *Verticillium dahliae* or *Phytophthora cactorum*. The runners (new plantlets that are on the stolon) are collected during the summer, planted in small pots and stored in winter.
Almost all partners used explants cleaning methods such as in vitro culture to have viruses free plants. The in vitro technique allows obtaining healthy plants which can be further planted in greenhouses or in fields. In vitro culture (culture in glass tubes) conditions are quite similar between partners. For adaptation in greenhouse conditions, all partners used standard procedure - transferred plants to a peat substrate and covered them for 1-4 week in the greenhouse.

Cryopreservation:
The use of cryopreservation has been initiated. Pieces of plants are placed in -80°C which will allow a more efficient long term preservation of plant materials.
(ii) Raspberry

Raspberry collections can be maintained in open field organised in rows. Clean straw, rotted sawdust, screened bark or similar organic mulch can be used in field rows for weed control and moisture preservation. The raspberry must be kept free of weeds, watered when necessary, fertilized, pruned regularly, kept free of insect and disease pests, and in some cases, supported with trellis.

Isolated fields for in situ conserving raspberry genetic resources in the James Hutton Institute (JHI)

1.4. Characterisation of the collections

Descriptors for characterising collections of strawberry and raspberry were separated into primary and secondary descriptors. Primary descriptors are stable whatever the condition of cultivation, in greenhouse or in field, while secondary descriptors can be more. Primary descriptors were mandatory and recorded by all partners. Secondary descriptors were established when available according to each location. A table for descriptors was set up.

For strawberry, there are 8 primary descriptors for the plant and 10 for the fruit, and 33 secondary descriptors for other plant and fruit characteristics diseases, pathogens and abiotics stresses behaviour. The characterisation of each strawberry cultivar also includes the passport data for the identification of the cultivar.

For raspberry, there are 9 primary descriptors for the plant and 8 for the fruit, and 33 secondary descriptors.

For strawberry: all the primary and secondary descriptors are available at: 
For raspberry: all the primary and secondary descriptors are available at: 
The passport data for strawberry cultivars are available on the Genberry portal at:
https://www.bordeaux.inra.fr/genberry/.
1.5 Towards a core collection for strawberry

For strawberry, a core collection was established for old European varieties selected before 1940. These varieties have shown specific diversity compared to varieties from more recent origins. In addition, the collection includes varieties and genotypes (plants that were selected but not used commercially) that have original traits such as high health compound contents (e.g. total antioxidant compounds) or high level of disease resistances (e.g. *Phytophthora cactorum* and/or *Verticillium dahliae*). Finally, important varieties for European countries (including local varieties well adapted to a particular country) were also included in the collection.

For raspberry, this project allowed to initiate the collection of data on genetic resources available in Europe, to draw a list of passport data and descriptors and to characterise collections using these criteria. In contrast to strawberries no database was established for raspberries because the objective of this project was to initiate the study of diversity of available collections.

2. Communication value

A Genetic Resources Network has been set up by 10 partners of the project to maintain their collections.

For strawberry, this network lists a total of 790 genotypes of the cultivated strawberry which are located in one or several conservation sites of the project. This network is accessible via https://www.bordeaux.inra.fr/genberry/. Part of these varieties was maintained as in vitro culture.

<table>
<thead>
<tr>
<th>Partner’s N° &amp; name</th>
<th>Number of varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 CRA-FRF, IT</td>
<td>232</td>
</tr>
<tr>
<td>2 UNIVPM</td>
<td>27</td>
</tr>
<tr>
<td>3 INSAD, PL</td>
<td>196</td>
</tr>
<tr>
<td>4 LIH, LH</td>
<td>94</td>
</tr>
<tr>
<td>5 CIREF, FR</td>
<td>157</td>
</tr>
<tr>
<td>6 JKI, GE</td>
<td>279</td>
</tr>
<tr>
<td>8 IFAPA, SP</td>
<td>289</td>
</tr>
<tr>
<td>9 FRIP, RO</td>
<td>113</td>
</tr>
</tbody>
</table>

This represents a total of 1387 individuals from which 1228 were included in the database.

For raspberry, 90 varieties were maintained by the partners.
3. The Action and the Partners

3.1 Action details

The GENBERRY project was awarded 339,545 euros from the EU, towards a total project cost of 710,099 euros. The project started on 01 September 2007 and ended on 31 March 2011. INRA Bordeaux/France served as the action’s coordinator. The project was implemented by ten partners in the following eight EU Member States: Italy, Spain, France, United Kingdom, Germany, Poland, Lithuania and Romania.

3.2 Partners

INRA-UMR-BFP, Béatrice Denoyes, Villenave d’Ornon Cedex, France

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INSAD, Research Institute of Pomology and Floriculture, Edward Zurawick, Pomologiczna 18, PO Box 105, 96-100 Skierniewice, Poland

Lithuanian Institute of Horticulture, LIH, Audrius Sasnauskas, Kauno 30, 54333 Babtai, Lithuania

Création Variétale Fraises - Fruits Rouges, CIREF, Philippe Chartier, Maison Jeannette, 24140 Douville, France

Julius Kuehn Institute, Research on Horticultural and Fruit Crops, Monika Höfer, Pillnitzer Platz 3a, 01326 Dresden, Germany
4. Links

4.1 The Genberry portal

More information on the achievements, as well as the contact persons of the different partners, can be found at: https://www.bordeaux.inra.fr/genberry/pages/sum.htm
4.2 The Genberry database for strawberry

For cultivated strawberry, a database was created and is accessible to the public at: http://www.bordeaux.inra.fr/eustrawberrydb/ and contains 1017 accessions (one accession represents a variety observed in one location). These accessions are physically represented by 1228 individuals, where each one is represented by 2 to 10 plants, located in pots or in container, and is physically located in one of the conservation sites. For the cultivated strawberry, 8 conservation sites located in seven countries were included in the study (see Table 2).

Primary descriptors, fruit descriptors and passport data were mandatory, secondary descriptors were recorded (see page 7). Molecular markers were recorded in three locations, France, Italy and Spain.

The core element of the GenBerry database is the ACCESSION (variety and genotype observed in one location). The accession can be represented by one or several INDIVIDUALS (entity which was observed) physically located in a conservation site.

There were three different categories of descriptors: the standardized FAO/IPGRI Multicrop Passport Descriptors, the phenotypic traits descriptors and molecular descriptors. These descriptors were configured by the administrator of the database. The administrator can make also future changes, (ie. add new descriptors).

This database could be used as model for a raspberry database.

Portal of the GENBERRY strawberry database (http://www.bordeaux.inra.fr/eustrawberrydb/)
Publications from partners


Final meeting of the GenBerry project in INRA Bordeaux