Conservation and Use of Vegetable Genetic Resources: A European Perspective

Lorenzo Maggioni
International Plant Genetic Resources Institute
Regional Office for Europe
Maccarese, Roma
Italy

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Abstract

The status of conservation of vegetable crops germplasm has always received less attention than that of the major staple crops such as cereals and legumes. Information on vegetable germplasm can, however, increasingly be obtained from online international databases. Maintenance and updating of this information requires a high level of international collaboration. This can be exemplified by the activity of the Working Groups of the European Cooperative Programme for Crop Genetic Resources Networks (ECP/GR)) on *Allium*, *Brassica*, Solanaceae and Umbellifer crops. Cost-effective and reliable ex situ conservation remains a challenge that can benefit from sharing responsibilities within crop networks. In these fora, the discussion of common problems (long-term storage, safety-duplication, regeneration) can lead to effective collaborative solutions. The databases, holding mainly passport data, can be analyzed for the identification of duplications and gaps among collections. International projects on the characterization and evaluation of vegetables germplasm, including molecular tools, are generating new data and making them increasingly available. Thus genebank material is becoming more attractive to breeders. At the same time, the management of collections can be based on better knowledge of the diversity in stock. The enhancement of the links between germplasm conservation and use will continue to depend, inter alia, on easy access to the genetic material. The recently approved International Treaty on Plant Genetic Resources for Food and Agriculture established a Multilateral System for facilitated access to germplasm of a number of crops. This includes vegetables such as asparagus, beet, the *Brassica* complex, carrot and eggplant, but excludes tomato, pepper, cucurbits, alliums, etc., with possible implications on the use of these crops' diversity in the near future.

INTRODUCTION

Vegetable crops include a large number of species, mainly used as an essential complement to the daily diet, providing vitamins, minerals, fibre, specific aminoacids and other active metabolites. Increasing the use of vegetables is considered to offer healthy benefits in all dietary situations. Some vegetables such as tomatoes, cabbages, watermelons and onions are among the most important crops according to total world production (FAO, 2001). Many others have lower global importance, but their production and use represent relevant nutritional and economic value in specific areas, i.e. asparagus in Europe, traditional leafy vegetables in Africa (Chweya and Eyzaguirre, 1999), etc.

Several authors have reviewed vegetable genetic resources in the last twenty years (Sloten, 1980; Crisp and Astley, 1985; Kalloo, 1988; Cross, 1998), largely emphasizing the need to accumulate and conserve in genebanks the genetic diversity that is most useful to breeders. One of the primary reasons to sustain conservation of plant genetic resources in genebanks is to prevent the loss of genetic diversity. The great diversity of types in cultivation is also considered a genetic resource itself, to be maintained or increased, since it adds to the diversity of vegetables being grown and consumed and could serve to replace more established but similar crops in case of need (Crisp and Astley, 1985).

The risk of genetic erosion due to the introduction of single new cultivars was

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considered especially high by Crisp and Astley (1985) for those vegetables that are built on a narrow genetic base, such as garlic, broccoli, tomato, cucumber, etc. Genetic erosion is difficult to document with solid data. In 1975 Innes (1975), consulting British seed catalogues, found that thirty-two Brussels sprout varieties offered in 1965 were no longer available in 1974 and that the number of hybrids on sale had increased from one to forty-one during the same period. The introduction by the European Community of a Common Catalogue of marketable vegetable varieties was followed in 1980 by the exclusion from the catalogue of 1500 variety names from 23 vegetable crops. These were considered as synonyms of registered varieties. However, Mooney (1983) argued that 62% of these were actually distinct varieties without owner and that seed companies were encouraged to eliminate them from the market as unwanted competitors, thereby provoking their likely extinction. Maggioni and Soressi (1992) surveyed the literature for names of Italian vegetable varieties and found 33 broccoli and 25 watermelons that were presumed to be extinct. They also compared old seed catalogues of the Italian company "Fratelli Ingegnoli" and found that during the forties only local types were offered; in the sixties, these were joined by an equal number of foreign varieties, while in 1990 only US varieties and hybrids were offered. Although these examples, related to Europe, cannot provide a quantitative measure of genetic erosion, they are indicative of a trend of variety turnover and displacement.

On a global level, efforts of the International Board for Plant Genetic Resources (IBPGR, now IPGRI) to conserve vegetable crop germplasm began in 1980, with the definition of a number of priority crops for conservation, according to their importance for rural development and to their economic value for farmers in the tropics (*Abelmoschus esculentus* and related species, *Allium* spp., *Amaranthus* spp., *Brassica* spp., *Capsicum* spp., *Cucurbita* spp., *Lycopersicon esculentum*, *Momordica charantia* and related species, and *Solanum melongena*) (Sloten, 1980). Action on this list of crops included the identification of existing collections, assignment of responsibility to specific genebanks and production of descriptors to facilitate characterization.

After a brief analysis of the increased size of the world vegetable collections in the last twenty years, this paper will focus its attention on the efforts made by the European region to collect, document, characterize, manage and use genetic resources of specific vegetable crops. These are, to some extent, the results of the activity of the Vegetables Network of the European Cooperative Programme for Crop Genetic Resources Networks (ECP/GR) (www.ecpgr.cgiar.org). This Programme, initiated in 1980, is self-funded by the European member countries and coordinated by the International Plant Genetic Resources Institute (IPGRI). In the case of beets, potatoes and legumes, it is difficult to distinguish accessions used for vegetable or dry-grain/industrial use and these crops have not been considered in the article.

DOCUMENTATION OF VEGETABLE GENETIC RESOURCES

Documentation at the Global Level

According to Plucknett et al. (1987), a major push to preserve the genetic diversity of vegetables resulted in the doubling in size of vegetable germplasm collections within the five years following IBPGR's intervention in the conservation of vegetable germplasm. They already considered the size of the world collections of landraces of tomato, peppers and amaranths as almost complete in the mid-eighties. According to the data of the FAO World Information and Early Warning System (WIEWS) (http://apps3.fao.org/wiews), in the following fifteen years the number of accessions of major vegetables conserved in genebanks doubled again or even tripled (Table 1). A 1998 FAO estimate regarded vegetable accessions to be about 8% of a total of around 6 million accessions in ex situ collections. The large majority of these vegetable accessions is represented by the IBPGR priority crops, while minor vegetables (possibly more than 2000 species are used in the world) are numerically much less represented. Cross (1998) considered the comprehensiveness of the collections still inadequate or poor, with the

exception of tomato, on the basis of the absolute numbers available and the extent of their provenance from the centres of diversification. It is, however, difficult to make objective statements since a complete analysis of the level of duplication of the world collections and of the actual coverage of genetic diversity of each genepool is not available.

Documentation in Europe

Considering the main European vegetables (*Lycopersicon* sp., *Brassica oleracea*, *Allium* sp., *Citrullus* sp., *Daucus* sp., *Cucumis* sp., *Capsicum* sp., *Lactuca* sp., *Cucurbita* sp. and *Solanum melongena)* the total number of ex situ accessions recorded by FAO – WIEWS in August 2002 is about 116,500, that is 42% of the world total for the same categories (Table 2).

The FAO - WIEWS database includes metadata obtained from many different sources, at different times, and offers an approximate indication of the real situation. Data at the accession level can increasingly be obtained from the European Central Crop Databases developed by the ECP/GR Working Groups in the last twenty years. This effort required strong collaboration and coordination, since accessions are maintained in over 500 European holdings. Institutions managing ECP/GR Central Crop Databases make this commitment on behalf of all the other member countries. The adoption in 1996 of the FAO/IPGRI list of Multi-crop passport descriptors for data exchange was a landmark in standardization throughout the European region (Lipman et al., 1997). On a crop by crop basis, a small number of discriminant characterization data were also collected and recorded in the central databases. These are the descriptors that should be of major interest to the breeders. At present, most of the online vegetable databases (*Allium*, *Brassica*, *Lactuca* and Umbellifer crops, (www.ecpgr.cgiar.org/Databases/Databases.htm) mainly offer passport data, although additional data may be available from the database managers. When data coverage is good in the relevant descriptors (collecting number, donor institute, donor number, safety-duplicate site, etc.), these databases can be used to monitor the level of safety-duplication or unnecessary duplications in the European collections. They can also be used as a tool to define priorities on a regional level for regeneration or for collecting missions. Although the use of passport data may seem limited and insufficient to raise breeders' interests, their value should not be underestimated. The geographic origin of the accessions, especially if detailed with geographic coordinates and/or environmental data, together with taxonomic data, is one of the most useful criteria used to select interesting accessions and /or to build core collections (Hazekamp, 2002).

In the near future, further integration of the European plant genetic resources documentation systems is expected thanks to the creation of the European Internet Search Catalogue (EURISCO). This online catalogue of all European crops' passport data (www.ecpgr.org/eurisco) is expected to be launched by September 2003 and to display searchable passport data automatically retrieved from the European countries' national inventories. Once EURISCO becomes the preferred and most reliable source of passport data, the Central Crop Database managers will be able to dedicate more time to gathering characterization and evaluation data and to analyzing the available information.

CONSERVATION, MANAGEMENT AND USE OF VEGETABLE CROPS IN EUROPE

Allium

1. Conservation and Documentation. A study on genetic resources of *Allium* spp., prepared by Astley et al. (1982), traced about 9400 accessions of cultivated and wild *Allium* in the major world collections. According to the online FAO - WIEWS, this figure after 20 years is almost three times higher (Table 3). Astley et al. (1982) identified 19 major collections. These same collections host today more than 50% of the world's accessions. Many other small and medium sized collections are distributed around the world, totalling 137 collections in 66 countries.

Allium collections in Europe have grown in size in the last twenty years, due to extensive collecting activity and acquisition of germplasm. In particular, missions to fill gaps in the collections were organized in Albania, Bulgaria, Czech Republic, Greece (wild species), Poland, Portugal and Spain (onion and garlic landraces), Scandinavia (shallots, potato–onions and chives), Turkey, F.R. Yugoslavia and in areas of the former Soviet Union (Kazakhstan, Uzbekistan, Altai mountains, western Siberia). Combining various sources of complementary data, the total number of *Allium* accessions in European genebanks, distributed in 27 European countries, can be estimated at around 18,000 (Table 3), representing over 60% of the world *Allium* accessions. The following collections assume a special significance for the region, since they are maintained by the hosting countries, on behalf of other member countries, as inputs in kind to the ECP/GR Cooperative Programme:

- Seed *Allium* species collection, Genetic Resources Unit, Horticulture Research International (HRI), Wellesbourne, United Kingdom. The material conserved here includes 131 advanced European leek cultivars, 124 onion landraces, mainly from Spain and Portugal, and 850 advanced onion cultivars from Europe and the rest of the world (Australia, Brazil, India, Japan, Pakistan, New Zealand, USA, etc.).
- The European field collection of long-day *Allium* species, Vegetable Section, Genebank Department, Research Institute of Crop Production, Olomouc, Czech Republic. This collection comprises 641 garlic accessions originated from more than 15 countries and 119 shallot accessions, mainly from Finland and Norway (Staveliková, 2002)
- The European field collection of short-day *Allium* species, Faculty of Agricultural, Food and Environmental Quality Sciences, Rehovot, Israel. This collection, supported by the Israeli Gene Bank, includes garlic, shallot, elephant garlic and *A. tuberosum* from the short-day zone, also from southeast Asia and South America (Rabinowitch, 2002).

The following collections also have a unique character:

- The taxonomic *Allium* Reference Collection and the in vitro *Allium* collection, Institute of Plant Genetics and Crop Plant Research (IPK), Gatersleben, Germany. The living collection of nearly 400 wild *Allium* species is a unique reference for taxonomic investigation of all the *Allium* species (Fritsch, 2002), while the in vitro collection includes 372 accessions of vegetatively propagated *Allium* species, including 98 virus-free garlic accessions (Keller and Senula, 2002).
- The decorative *Allium* species collection, Department of Floriculture, Volcani Centre, Bet Dagan, Israel. This includes about 200 entries and is used to study floral induction and florogenesis as well as the potential of some species as decorative crops.
- The von Bothmer collection, Plant Research International, Wageningen, The Netherlands. Collected mainly from the Greek Islands (Bothmer, 1974) it now contains 73 different clones of species from the so-called ampeloprasum complex (Kik, 2002). It was found to be of potential value for finding male sterility sources to be introduced in leek (Kik et al., 1997).

Following the first meeting of the ECP/GR *Allium* Working Group in 1984, the European *Allium* Database (EADB) was established at HRI, Genetic Resources Unit, Wellesbourne, UK. The current version of the database is searchable online (http://www.hri.ac.uk/site2/research/PGB/ecpgr/ecpgr.htm) and contains specific information on 7832 accessions representing the 5 major *Allium* crops and wild taxa from 8 institutions in 8 countries, plus the Nordic Gene Bank. Available data are passport descriptors based on the standard FAO/IPGRI Multicrop List and additional crop specific descriptors, such as the common name, mode of reproduction and day length requirements. An analysis of the data available informs us that 2800 accessions of *Allium cepa* originate from 104 different countries, the most numerous being from The Netherlands (9%), USA (7.4%) and United Kingdom (7.4%); overall, 1394 accessions are recorded as landraces, 2519 as advanced cultivars and 1555 as wild species. Specifically, 433 *A. cepa* landraces originate from 64 countries (14% from Portugal, 13 % from

Russian Federation, etc.); on the other hand, 733 *A. sativum* landraces originate from 52 countries (32% from the Russian Federation and the former Soviet Union; 14% from the Czech Republic and former Czechoslovakia, 8% from Spain, etc.); the oldest sample was collected in 1909 (*A. hissaricum* from Tajikistan), while 6% of the samples for which the acquisition date is known were entered into the genebanks before 1960 and more than 70% were acquired after 1980. A registered safety-duplication site is recorded for 728 accessions (9.2%).

2. Management of the European Collections. The regeneration of outbreeding seed propagated *Allium* accessions in isolation cages is an expensive practice and European curators agreed to prioritize the regeneration of material of national origin. Protocols for the use of pollinators have been shared and published by the ECP/GR *Allium* Working Group members (Keller and Hammer, 1999; Kotlinska, 1999). In an effort to reduce the number of duplicate accessions in European collections, a rationalization trial was set up in The Netherlands, in the framework of the EU funded project GENRES 20 (Astley, 2002). Onion and leek accessions with the same name, received from partner genebanks, were planted together for visual comparison by variety testing specialists. Thus it was possible to regard a number of onion accessions belonging to the Rijnsburger group as real duplicates and to suggest their elimination.

Safety-duplication of the collections is an ongoing recommended safety-measure; however, less than 10% of the accessions have a safety-duplication site registered in the EADB. Duplication of *Allium* seed accessions is regularly made between HRI and the Centre for Genetic Resources, The Netherlands (CGN), with about 70% of HRI accessions safety-duplicated at CGN and about 85% of CGN accessions safety-duplicated at HRI. Otherwise, seed accessions are only occasionally safety-duplicated. National genebanks in Germany, Poland, The Netherlands, UK and the Nordic Gene Bank offered to host safety-duplicates of seed accessions under bilateral agreements (Maggioni et al., 1999).

Several taxa in the *Allium* genepool have to be propagated vegetatively. These are seed sterile (garlic, great headed garlic, leek relatives and *A. chinense*), or have partly lost their fertility (shallot), or their fertility is poor because of maintenance in inappropriate environmental conditions (wild species). The maintenance of accessions vegetatively is extremely expensive, time consuming and has associated phytosanitary risks. Nevertheless, collections have grown in several countries (Astley and Keller, 2002). The ECP/GR *Allium* Working Group has proposed a strategy to create a network of specialized centers for the conservation of vegetatively propagated *Allium* to share the costs of conservation and improve the security and the quality standards of the European collections. All the different vegetative *Allium* accessions currently conserved in Europe should be identified so as to become part of a “European collection”. The responsibility for maintaining crop subsets of this collection could be accepted by two or more genebanks, designated on the basis of the climatic requirements of the different crops and of existing conservation expertise. Therefore, each accession would be maintained in more than one location as a safety-duplication measure. Increasing the use of in vitro conservation for safety-duplicates and improving cryopreservation technologies were also recommended as part of the overall strategy (Maggioni et al., 2002).

3. Use of the European Collections. The EU-funded four-year project (GENRES 20) supported characterization for morphological descriptors of 532 onions, 168 leek and leek relatives, 285 garlic, 36 chive, 17 shallot and 4 *A. fistulosum* accessions. All the data are publicly available and expected to be linked to the online EADB. Moreover, preliminary core collections for onion, leek and garlic were developed. Onion and leek cores, consisting of 268 and 48 accessions respectively, represented 10% of the available crop genepool documented in the EADB. Criteria for selection of the accessions included wild/cultivated taxon, crop type or varietal group, day-length adaptation and country of origin. A core collection of garlic was also developed consisting of 25 long-day and 25 short-day varieties. The project also resulted in the evaluation of leek and wild relatives for resistance to white tip disease (*Phytophthora porri*), rust (*Puccinia porri*) and thrips

(*Thrips tabaci*). Sources of resistance were identified in all cases. Onion germplasm was evaluated for resistance to downy mildew. Although no resistance was identified in this case, variable levels of infection between accessions were recorded.

4. Wild Genetic Resources and In Situ Conservation. Holubec (1999) pointed out the presence in Europe of 110 wild and cultivated species, many of which are edible or could be used for breeding purposes. Kik et al. (1997) recently demonstrated the possibility to use the genetic variation of the wild relatives of leek from the *A. ampeloprasum* complex. Sources of resistance to fungi and insects were also recently found in wild relatives of onion (Galván et al., 1997; Zheng et al., 2000). Hanelt (1990) reported that relatives of *A. cepa* in the Irano-Turanic region of Soviet Central Asia were under threat of extinction due to overgrazing and overcollection. Rabinowitch (2002) recently confirmed that the *Allium* genepool is under considerable threat in Central Asia due to massive commercial collection of wild plants such as *A. longicuspis*, *A. motor* and *A. odorum*. The threat to wild *Allium* populations in Bulgaria (Maggioni et al., 1999) and Poland (Kotlinska, 1996) has also been mentioned. On the other hand, the variability of species belonging to the *A. ampeloprasum* complex in Greece and other parts of Europe was indicated as deserving investigation, but not under threat of genetic erosion (IBPGR, 1992). It seems appropriate to encourage the conservation of the environment in which wild *Allium* species occur (Gass et al., 1996), however, an ecogeographic survey of wild *Allium* species in Europe and Central Asia would be the necessary basis to suggest the most appropriate and effective measures of in situ conservation.

Brassica

1. Conservation and Documentation. Genetic resources of *Brassica* were recently reviewed by Boukema and Hintum (1999). They traced from various sources an indicative total of about 74,000 accessions, the majority of which is conserved in Europe (41%) and Asia (41%) and lower percentages in the Americas (12%). The most important vegetable *Brassica* species (*B. oleracea* and *B. rapa*) were represented respectively by about 20,000 (27%) and 18,000 (25%) accessions worldwide. Detailed accession data for 32 collections in 22 European countries can be obtained from the European *Brassica* database (Bras-EDB) (www.cgn.wageningen-ur.nl/pgr/collections/brasedb/), which is maintained by CGN, following a decision made in 1991 at the first ECP/GR *Brassica* Working Group meeting (IBPGR, 1993). The Bras-EDB contains FAO/IPGRI Multi-crop passport and additional data such as common name, end use and ancestral information. The most represented species is *Brassica oleracea* with 10,252 accessions, followed by *B. napus* (3787), *B. rapa* (3022), *B. juncea* (647) and *B. carinata* (310). Table 4 shows the number of accessions of the main *B. oleracea* varietal groups conserved in 22 European countries and how they are distributed in several countries. The largest *B. oleracea* collections are found in the United Kingdom (2152), Germany (1422), Spain (1237) and Russian Federation (978). Considering specific varietal groups, the fragmentation of the collections becomes clearer. For example, in the case of cabbage, 90% of the accessions are held by ten countries, i.e. Russian Federation (20%), Germany (19%), UK (17%), Spain (9%), The Netherlands (7%), F.R. Yugoslavia (5%), and 3% each in Czech Republic, Poland, the Nordic Gene Bank and Ukraine. In the case of cauliflower, seven countries hold 86% of the accessions: UK (29%), France (15%), The Netherlands and Russian Federation (10% each), Poland (9%), Germany (7%) and Spain (6%).

Further analysis of the *B. oleracea* component of the Bras-EDB shows that accessions originate from 86 countries. The most represented are Spain (12%), UK (10%), The Netherlands (10%), France (9%) and Portugal (8%). Advanced cultivars and landraces respectively represent 37% and 27% of the database. A small number of accessions (344) were collected before 1950, while more than 75% were acquired after 1980. Many of these samples derive from the EC funded collecting missions carried out in the EC countries in the early eighties (Meer, 1984).

2. Management of the European Collections. Within the framework of ECP/GR, the United Kingdom accepted to maintain the collection of Cruciferous crops at HRI,

Wellesbourne on behalf of the region. The same service is offered by Spain for wild Brassicas and related wild relatives, conserved at the Polytechnical University, Madrid. However, HRI currently stores about 16% of the European *Brassica* accessions and the collections remain fairly decentralized. The ECP/GR Working Group on *Brassica* promoted efforts to rationally manage the European collections by reducing duplicates, arranging for safety-duplication and improving regeneration procedures (Maggioni, 1998). More recently, recommendations for bilateral safety-duplication and minimum guidelines to be followed for the regeneration of *Brassica* accessions were agreed by the Group (Maggioni and Thomas, 2002).

3. Use of the European Collections. In the course of an EU AIR3 funded project, started in 1992, a *Brassica oleracea* core collection was developed to facilitate screening of the available genepool for resistance to downy mildew (*Peronospora parasitica*), white blister (*Albugo candida*) and the cabbage aphid (*Brevicoryne brassicae*). The development of this collection, consisting of 411 accessions, was based on the possibility to hierarchically subdivide accessions in the Bras-EDB using botanical and provenance data (Boukema et al., 1997). Selected accessions were obtained from several genebanks of the European network and proved valuable in identifying hot spots for resistance (Astley et al., 1997). A more recent EU funded project (GENRES 109-112) started in 2000, aimed at establishing and characterizing core collections of *B. oleracea*, *B. rapa*, *B. napus* and *B. carinata*. Cores including 396 *B. oleracea* and 100 *B. rapa* accessions were selected from the Bras-EDB to represent the available diversity (Soest et al., 2002). Preliminary screening of the *oleracea* collection identified a few accessions resistant to clubroot (*Plasmodiophora brassicae*), to blackrot (*Xanthomonas campestris*) and to *Mycosphaerella brassicicola*, particularly in red cabbage (Bas et al., 2002). The screening of the *rapa* collection also gave encouraging preliminary results, with 20% of the accessions showing resistance to *Albugo candida* isolate 7V (Astley and Pinnegar, 2002).

4. Wild Genetic Resources and In Situ Conservation. Boukema and Hintum (1999) traced 412 accessions of 23 wild *Brassica* species in genebanks. The large majority (389) is conserved in European genebanks, in particular at the University of Madrid, Spain (179) and at IPK, Gatersleben, Germany (97) (Boukema et al., 2002). Considering that 116 accessions only belong to *B. cretica*, it is fair to say that wild species are under represented in the ex situ collections, although IBPGR-funded missions in the eighties have allowed the collection of germplasm from about 200 localities hosting wild relatives of the (n=9) *B. oleracea* cytodeme (Gómez-Campo and Gustafsson, 1995). This group of species, all interfertile with the *B. oleracea* crops, is distributed along the Atlantic coasts of Britain, France and Spain and along the Mediterranean coasts from Israel to northeast Spain, with centres of diversity in the Aegean islands and Sicily (Gustafsson, 1995). The importance of protecting the natural habitats of wild Brassicas and the opportunity to establish in situ conservation programmes in the Mediterranean were stressed on several occasions (Gustafsson, 1995; Maggioni et al., 1997). Traits of interest in wild species include the presence of high contents of potentially health-inducing glucosinolates (Branca et al., 2002) as well as resistance to insects (Eastwood, 1996; Warwick, 1993; Ellis et al., 2000).

Umbellifer Crops

1. Conservation and Documentation. 1998 saw the establishment of an Umbellifer crops Working Group, resulting from the need expressed by a group of workers interested in carrot to collaborate in the conservation of European *Daucus* genetic resources (Astley, 1999).

The Group decided to focus on eight crops regionally or locally important in Europe, including the genera *Anethum* L. (dill), *Apium* L. (celery), *Carum* L. (caraway), *Chaerophyllum* L. (chervil), *Coriandrum* L. (coriander), *Daucus* L. (carrot), *Foeniculum* Miller (fennel), *Pastinaca* L. (parsnip), and *Petroselinum* Hoffm. (parsley). In the case of carrot, the expanding world production, reaching nearly 20 million tons in 2001, has been accompanied by genetic simplification and the replacement of the local diversity by F_1

hybrids. In celery, the leading variety 'Monarch' occupies over 50% of the market share in Europe and older varieties have been largely replaced, although their high content of etheric oils makes them tolerant to the main celery diseases (Frese et al., 1999). In the other selected crops, the tendency is to replace existing diversity, made up of heterogeneous varieties and local types, with a few hybrids or selected cultivars. Since 1997, intensive collecting missions have been organized by the Polish Gene Bank and the United States Department of Agriculture, in collaboration with the respective national genebanks, in Greece, Moldova, Poland, Slovakia, Syria, Turkey and Ukraine. These missions resulted in the addition to the collections of about 80 carrot landraces, over 500 wild carrots and nearly 200 other umbellifer species (Astley and Kotlinska, 2001). The Group is, however, aware of the need for further collecting, especially of local cultivars and wild species in the Mediterranean countries.

A few important collections of *Daucus* exist in the USA and China. However, around 70% of the carrot germplasm is conserved in European genebanks. The European Umbellifer Database (EUDB), maintained by HRI, Wellesbourne, United Kingdom, was established in 1997 under the auspices of the ECP/GR umbellifer curators (http://www.hri.ac.uk/site2/research/pgb/ecpgr/umbellifer/umbellif.htm). The database contains passport data on 8870 accessions, including the FAO/IPGRI Multicrop Descriptors, plus additional data such as the root type group and the location of the safety-duplicates. These data represent the 9 major umbellifer crops and a range of wild taxa from 16 institutions in 12 countries plus the Nordic Gene Bank. Carrot accessions represent 65% of the data, parsley 8%, coriander 6%, while data for each other genera are less than 5%. Accessions originate from 104 countries, with the most represented being Germany (6%) United Kingdom (5.5%) and The Netherlands (5.5%). The United Kingdom, Germany and Russian Federation host the largest collections, jointly totalling more than 65% of the accessions. Overall, 2737 accessions are advanced cultivars, 1073 are wild samples and 941 are landraces. The collection date is known for 30% of the accessions, of which 350 were obtained before 1960, while the majority were collected in the eighties and nineties. The oldest samples, dating as far back as 1924, are conserved at the N.I. Vavilov Institute, St. Petersburg, Russian Federation, consisting of seed samples shipped by US and European breeding companies, as well as of landraces from West and Central Asia (Khmelinskaya, 1999).

2. Management of the European Collections. Following communication to the Working Group of the need for urgent regeneration of some accessions of the Vavilov Institute collection, four national programmes (France, Italy, Poland and UK) took action and regenerated more than 100 samples between 1998 and 2002.

According to the EUDB, only 10% of the accessions have a registered safety-duplication site.

3. Use of the European Collections. A four-year EU funded project (GENRES 105) on carrot genetic resources started in January 2000. The project supported the regeneration of the European collections for characterization and evaluation. In particular, HRI is carrying out evaluation for resistance to carrot fly (*Psylla rosae*) and soilborne disease cavity spot (*Pythium* sp.). The Institut National d'Horticulture, Angers, France and the Federal Centre for Breeding Research on Cultivated Plants, Quedlinburg, Germany are evaluating resistance to *Alternaria dauci* and the University of Bologna, Italy and the Nordic Gene Bank, Alnarp, Sweden are analyzing sugar, carotene and nitrate content of the collections.

Leafy Vegetables

1. Conservation and Documentation. Several vegetables used for consumption of the leaves (lettuce, spinach, etc.), stems (asparagus), petioles (rhubarb) or inflorescences (artichokes) are often included in the category of "leafy vegetables". The limited representation of this type of germplasm in genebanks is an indication that they received less attention than other crops. Hintum and Boukema (1999a) recently reviewed the global status of genetic resources of the genera *Lactuca*, *Chicorium* and *Spinacia*. They were able to trace 18,970 accessions belonging to the primary genepool of *Lactuca sativa*

(including *L. serriola* and other sexually compatible species). The four largest collections (University of California, Davis, USA; Vegetable Production Research, USDA-ARS, Salinas, USA; CGN, Wageningen, The Netherlands and Western Regional Plant Introduction Station, USDA-ARS, Pullman, USA) were found to contain 50% of this total. In 1999 CGN took the initiative to establish an International Lactuca Database (http://www.cgn.wageningen-ur.nl/pgr/collections/ildb/) within the framework of the ECP/GR Vegetables Network. The database focuses on passport data of all *Lactuca* species of germplasm collections worldwide. The data are presented in a format based on the FAO/IPGRI Multi-crop Passport Descriptors. The database includes data for 12,028 accessions held in 21 collections in 15 European countries (9235 accessions) plus the USA (2765) and Iran (28).

Within the framework of ECP/GR, Lebeda and Boukema (2001) reviewed the status of European collections of *Lactuca*, *Cichorium*, *Spinacia*, *Atriplex*, *Valerianella*, *Rumex*, *Portulaca*, *Tetragonia* and *Asparagus*. In the case of *Cichorium*, combining the data traced in Europe by Hintum and Boukema (1999a) and by Lebeda and Boukema (2001), 12 collections from 7 countries hold a total of around 1800 accessions. Main collections are held in France (788) and Germany (505). About 1000 accessions of *Spinacia* were found to be distributed in 12 collections from 9 countries, with the largest collections in the Netherlands (382), Germany (202) and Turkey (150). A total of only 500 accessions were traced for the other six genera of minor leafy vegetables.

A considerable number of collecting missions have taken place all over Europe in the last ten years. Endangered landraces and wild relatives requiring collection are, however, still reported to exist in several countries, especially around the Mediterranean Basin.

2. Management and Use of the Collections. A comparison made by Hintum and Boukema (1999a) between three European and one American genebank, representing 28% of the world collection, estimated that 40% of their *Lactuca* germplasm was unique and the remaining fraction was duplicated at least once (30%) in the other genebanks. This result led the authors to suppose that duplication between the world's lettuce germplasm is enormous. Efforts to understand the distribution of genetic diversity in the collections could help define priorities for conservation and screening for breeding purposes. This was the general objective of a demonstration project funded by the EU and concluded in 2000, called "Molecular markers for genebanks: Application of marker technology for the improvement of ex situ germplasm conservation methodology". In this project, coordinated by CGN, the Netherlands, and involving six partners, the entire CGN lettuce collection (2320 accessions) was characterized with AFLPs and STMSs. The enormous amount of information generated is being used to address issues related to germplasm management and use (T. van Hintum, pers. commun.). Analysis of the level of genetic similarity between accessions gave insight on the opportunity of reducing the size of the collection. The different number of alleles detected in samples of different sizes gave a quantitative indication of the possible effects of sample size for accession multiplication. The analysis of diversity between and within accessions provided an understanding of the collection's genetic structure. This knowledge can help in validating the breeding system and the taxonomic classification of wild species and in assembling core collections. Molecular markers were associated to phenotypic traits, such as resistance to *Bremia*. A follow-up EU supported project, GENE-MINE, will focus on the development of software able to handle large amounts of genetic data and the application of molecular markers to screen *Lactuca* for variation to resistance genes.

Lebeda and Boukema (2001) reported that lettuce collections had been evaluated for resistance to LMV, *Bremia lactucae*, powdery mildew and to aphids. Some of these data are downloadable from the CGN web site (http://www.cgn.wageningen-ur.nl/pgr/collections/). On the other hand, only rare cases were reported of evaluation for disease resistance in the other crops, for which also morphological characterization is very limited, due to the lack of appropriate descriptors, as well as of specialized taxonomic expertise.

Solanaceae

1. Conservation of Genetic Resources. A survey of Solanaceae genetic resources in Europe was prepared by Daunay (2001), focusing on tomato, pepper and eggplant. On the basis of a questionnaire sent to holding institutions, Daunay was able to record 32 collections distributed in 20 countries, holding 23,421 tomato, 13,279 pepper and 4663 eggplant accessions. The figures reflect the different economic importance, as well as the long tradition of research and breeding, for these three crops in Europe. Large tomato collections are present in Russian Federation (7250 accessions), Germany (2624), The Netherlands (1750), Spain (1645), Hungary (1644) and Czech Republic (1604). These collections are rich, inter alia, in early cultivars adapted to cold conditions, isogenic lines and other material containing disease resistance genes. The main pepper collections can be found in Russian Federation (2313), Germany (1504), France (1400) and Hungary (1400). A duplicate of the Capsicum Genetic Cooperative collection, including morphological and physiological markers, is conserved at the University of Torino, Italy. European collections hold pepper accessions originated from all over the world, as well as characterized genetic stocks and resources evaluated for disease resistance genes. The University of Birmingham, UK (1200) holds an important eggplant collection, including several wild species, but the impossibility to continue its maintenance necessitated transfer of the collection to the Botanical Garden of Nijmegen, The Netherlands and to INRA, France, which also holds a very large collection of 1202 eggplants accessions.

2. Documentation, Management, and Use of the Collections. In 2001 an ECP/GR Working Group on Solanaceae was established. Together with an EU funded project on eggplant genetic resources (GEN RES 113), which started in 2000, the ECP/GR initiative will facilitate collaboration in Europe in the near future. The preparation of central inventories with passport data was planned in order to estimate the degree of duplication amongst collections. Responsibility for the eggplant inventory was assigned to INRA, Monfavet, France, the pepper to the Aegean Agriculture Research Institute, Izmir, Turkey, the tomato to the Vavilov Institute, St. Petersburg, Russian Federation and the *Cyphomandra* sp. and *Physalis* sp. inventories to the Polytechnic University of Valencia. Definition of common characterization and evaluation descriptors is the next target of the Working Group, in order to be able to compare material from different collections. Harmonized guidelines for eggplant seed regeneration and storage were already defined and agreed for common use.

Cucurbits

1. Conservation of Genetic Resources. The ECP/GR Vegetables Network agreed in 2000 to extend its activities to cucurbit genetic resources, starting with a survey of existing collections and the creation of an informal group of cucurbit experts and curators. A review of the state of cucurbit germplasm in European collections was prepared by Nuez and Diez (2001) and revised by Diez et al. (2002). On the basis of these surveys, European genebanks and breeder' collections contain more than 26,000 accessions of cucurbits, including the four major cucurbit crops (watermelon, squash and pumpkin, cucumber and melon), five other important crops (loofah, bottle gourd, chayote, wax gourd, bitter melon) and other less important cultivated species and wild relatives. More than half of these accessions belong to the genus *Cucumis* (about 5900 *Cucumis sativus* and 7500 *Cucumis melo*), almost 7000 accessions are of the *Cucurbita* genus and over 4300 of the genus *Citrullus* (about 3600 *Citrullus lanatus*) (Table 5). The three largest collections, the Vavilov Institute, St. Petersburg, Russian Federation, the Centre for Conservation and Breeding of Agricultural Biodiversity of the Polytechnic University of Valencia, Spain and the Genebank of the IPK, Gatersleben, Germany, collectively hold about 55% of the European cucurbit accessions.

2. Documentation and Use. Detailed analysis of the collections is not possible without central databases. However, Nuez and Diez (2001), considering available data from five large collections, were able to estimate that most of the cucurbit accessions are from Europe (66%) and Asia (23%), with lower representation of American (9%) and African

(2%) accessions. Very low numbers of wild species in the collections suggest the need to still collect diversity from the centres of origin. However, centres of differentiation of local genotypes, such as in the Balkans, are also considered valuable targets for collecting missions.

Although some of the collections have been screened for disease resistance and tolerance to biotic and abiotic stresses, the large majority has not been evaluated or insufficient information is available (Nuez and Diez, 2001). An EU funded project (GENRES 108) on "Management, conservation and valorization of genetic resources of *Cucumis melo* and wild relatives" is a first collaborative initiative, started in 2000 with four partners, aimed at establishing a central database on melon and a preliminary core collection. The ECP/GR informal group on cucurbits, that met jointly with the EU project partners in January 2002, is trying to extend collaboration in Europe to all the relevant genebanks and all the cucurbit crops. A first initiative is the development of a European Central Cucurbits Database at the Polytechnic University of Valencia, Spain and safety-duplication of the collections is planned. Harmonization of the regeneration guidelines and the primary characterization descriptors is also part of the proposed workplan (Diez et al., 2002).

SHARING RESPONSIBILITIES IN EUROPE

A few institutes with large vegetable collections can be found in Europe. The Vavilov Institute, St. Petersburg, Russian Federation is rich in germplasm of all crops and holds the largest collections in Europe of tomato, cabbage, leek and cucurbits. HRI, Wellesbourne, UK holds the largest collections of onions, cauliflowers and carrots. CGN, Wageningen, The Netherlands is very rich in lettuce germplasm. The German genebanks also hold vegetable collections of large sizes. However, it is rare to find a European institute or country holding more than 30% of the total number of accessions for a given crop. This fragmentation corresponds to the aspiration of each individual country to exercise its sovereignty over genetic resources, in line with the Convention on Biodiversity. On the other hand, no country can conserve all the useful diversity, because public funding for maintenance of the collections often remains below a sustainable level. Since a high level of interdependency characterizes this region, it is essential to find ways to share responsibilities and resources. The Nordic Gene Bank, based in Alnarp, Sweden, is shared by the five Nordic countries and has the mandate to conserve Nordic material (Thörn, 1999). This is the only example of a subregional collection in Europe. It is very efficient, but requires a very high level of cooperation among the countries involved. To some extent, also the Vavilov Institute, St. Petersburg, Russian Federation still maintains a subregional function, since it holds several accessions originated from the newly formed countries of the former Soviet Union. However, the tendency there is to repatriate material to the various countries, rather than formalize a subregional arrangement. Centralized collections on a crop-by crop basis, whereby partner institutions maintain a crop collection on behalf of the region, have also been established (seed *Allium* species and cruciferous crops collections in Wellesbourne, United Kingdom; the European field collection of long-day Alliums, Olomouc, Czech Republic; the European field collection of short-day Alliums, Rehovot, Israel; the wild Brassicas and related wild relatives collection, Madrid, Spain). This arrangement has several advantages related to specialization on a single crop, which allows reaching excellence in the management of the specific crop. Moreover, concentration of the entire crop diversity in one location facilitates research and acquisition of knowledge of the material in stock. This allows to better serve the user with complete information and the creation of core collections (Hintum and Boukema, 1999b). The above-mentioned centralized collections are the result of an autonomous decision made by a country or institution to dedicate resources to a given crop, generally of national interest. On the other hand, these are not arrangements collectively made by the countries of the region to share the task of conservation. Consequently, although these collections welcome genetic material received from other countries and ensure its conservation and open access, germplasm is not systematically

deposited in the central collections, the tendency being for each single country to try and maintain all its national genetic resources. This attitude brings into play another possible option for sharing responsibilities, i.e. the "decentralized European collection", whereby partner institutions maintain a number of accessions for each individual crop on behalf of the region (Gass and Begemann, 1999). This type of arrangement has not yet been formalized, but is a possible option for the future, making the need for collaboration even more essential. International agreements are necessary to adopt common standards for documentation; conservation protocols need to provide an agreed minimum quality level in order to ensure mutual trust; coordinated management is required to ensure arrangements for safety-duplication, while reducing the number of undesired duplicated accessions; a system of easy and quick access to the material needs to be established. The necessary spirit of collaboration has so far prevailed within the ECP/GR circles. This has helped to maintain an open exchange of information and material and to seek specific solutions in order to treat the regional germplasm as a shared asset.

ACCESS TO GENETIC RESOURCES

In November 2001 the FAO Conference adopted the International Treaty on Plant Genetic Resources for Food and Agriculture. This treaty is intended to regulate access to genetic resources, ensuring the sharing of the benefits arising from their use, in line with the Convention on Biodiversity. This legally binding treaty will enter into effect when ratified by at least 40 countries. Under its provision, a Multilateral System is established, ensuring facilitated access to genetic resources of a list of crops. Among the vegetables, asparagus, beet, the *Brassica* complex, carrot and eggplant are all part of the list, while tomato, pepper, cucurbits, alliums, lettuce, etc. are excluded. For crops included in the list, the signature of a standard Material Transfer Agreement will ensure easy exchange of material for the purpose of utilization and conservation for research, breeding and training for food and agriculture. It is hoped that also for non-listed crops, a Multilateral System approach will be voluntarily developed by parties concerned with the conservation of the crops. The opportunity for ECP/GR member countries to take this direction could also serve as example for other regions to follow.

CONCLUSIONS

Although precise information on the current number of vegetable accessions conserved in the world genebanks is not provided by any global documentation system, analysis of available data allows us to estimate that more than 40% of the ex situ vegetable germplasm is conserved in European genebanks. Public access to passport information has much improved in the region in the last five years, thanks to the deployment of several central crop databases on Internet. Collaboration among more than 30 European countries within the context of ECP/GR has been crucial during the past twenty years to allow harmonization and transfer of the data and to recently extend the scope of joint activities to the whole range of vegetable crops of regional importance. The imminent launching of an all crops online European catalogue of passport data, EURISCO, is expected to further strengthen the capacity of the national programmes to make updated national data available and to build a fully integrated documentation system.

During 1996-2003, a number of projects on vegetable genetic resources, providing specific EU funds (Regulation 1467/94) have enormously contributed to the management of the collections and the production of large sets of publicly available characterization and evaluation data. EU funded demonstration projects, such as lettuce molecular characterization, have shown a possible way to deepen knowledge of the existing collections and to improve their management and use. In the case of vegetables, which have not received the same attention as other crops in the past, it will be especially important that sufficient financial resources continue to be allocated to the maintenance of collections. It is common belief that in several locations, especially in the Mediterranean countries and in the marginal areas, vegetable landraces not represented in the genebanks

still exist. It would be important to promote collection of this germplasm and of wild species, together with initiatives to survey and to maintain in situ and on-farm genetic diversity. Now that an integrated and functional documentation system seems to be within reach in the region, thereby increasing awareness of the status and distribution of their genetic resources, the European countries should feel closer to taking further steps towards shared conservation and use of their genetic resources. The establishment of a regional multilateral system ensuring facilitated access to all crops and the formalization of mechanisms to share responsibility for conservation would help to preserve and use genetic resources for the common benefit in the most rational way.

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Tables

Table 1. Size of world vegetable collections (1987 – 2002).

Crop	Plucknett et al. (1987)	FAO – WIEWS 2002
Tomato	32,000	76,400[1]
Cucurbits	30,000	65,800[2]
Cruciferae	30,000	89,250[3]
Pepper	23,000	59,300
Allium	10,500	26,700
Amaranths	5,000	14,000
Okra	3,600	7,200
Eggplant	3,500	6,850

[1] *Lycopersicon* sp.
[2] *Citrullus* sp. and *Cucurbita* sp.
[3] *Brassica* sp. and *Raphanus* sp.

Table 2. Comparison of world and European vegetable collections (Source: FAO - WIEWS 2002).

Taxon	World	Europe	
	N. of accessions	N. of accessions	% of world accessions
Lycopersicon sp.	76,395	21,385	28%
Capsicum sp	59,303	18,326	31%
Cucumis sp.	29,869	15,899	53%
Cucurbita sp.	27,334	8,521	31%
Allium sp.	26.677	17,212	64%
Brassica oleracea	17,635	13,603	77%
Lactuca sp.	14,126	10,855	77%
Citrullus sp.	8,593	4,131	48%
Solanum melongena	6,839	2,029	30%
Daucus sp.	6,595	4,545	69%
Total	273,366	116,506	42%

Table 3. *Allium* accessions conserved in Europe (Data sources: European *Allium* Database -versions 2001 and 1999; FAO - WIEWS 2002; Maggioni et al. (1999); Maggioni et al. (2002)).

Allium species	No. of accessions	No. of countries holding *Allium* accessions	Countries (ISO codes) with largest collections (number of accessions)
A. cepa	5204	27	GBR (999); RUS (944); FRA (793); POL (408)
A. sativum	3995	18	ESP (713); CZE (641); DEU (486)
A. fistulosum	459	9	RUS (191); DEU (84); GBR (56)
A. ampeloprasum/ A. porrum	589+754	16	RUS (390); FRA (307) ; GBR (151)
A. schoenoprasum	112	12	DEU (54); BGR (16); GBR (11)
A. chinense	5	1	DEU (5)
A. tuberosum	57	4	DEU (40)
Wild species	6256	12	DEU (4300); GBR (769); ISR (420) POL (240)
Total *Allium* sp.	~18,000	27	

Table 4. Number and percentage of *B. oleracea* accessions in the Bras-EDB, per varietal group, and number of countries holding these accessions.

Varietal groups	No. of accessions	%	No. of countries holding accessions
B. oleracea var. *acephala* (kale)	1918	19	16
B. oleracea var. *alboglabra* (chinese kale)	65	0	4
B. *oleracea* var. *botrytis* (cauliflower)	1812	18	19
B. olearacea var. *capitata* (cabbage)	3595	35	21
B. olearacea var. *costata* (tronchuda)	218	2	6
B. oleracea var. *gemmifera* (brussels sprouts)	521	5	13
B. oleracea var. *gongylodes* (kohlrabhi)	319	3	15
B. oleracea var. *italica* (broccoli)	476	5	13
B. oleracea unknown	1328	13	17
B. *oleracea* sp. (total)	10,252	100	22

Table 5. Cucurbits accessions conserved in Europe (Diez et al. (2002)).

Taxon	No. of accessions	No. of countries holding cucurbit accessions	Countries (ISO codes) with largest collections (number of accessions)
Citrullus sp.	4303	10	RUS (2602); ESP (386); TUR (374)
Cucumis sp.	13,899	13	RUS (4931); ESP (2136) BGR (1247)
Cucurbita sp.	7163	12	RUS (2064); ESP (1274); DEU (857)
Other cucurbits	953	10	RUS (554); DEU (175); ESP (63)
Total	26,318	14	RUS (10151); ESP (3859); DEU (2261)