Journal für Kulturpflanzen, 71 (2/3). S. 41–51, 2019, ISSN 1867-0911, DOI: 10.5073/JfK.2019.02-03.01 Verlag Eugen Ulmer KG, Stuttgart

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German Fruit Genebank – looking back 10 years after launching a national network for sustainable preservation of fruit genetic resources

Deutsche Genbank Obst – Rückblick auf 10 Jahre nationales Netzwerk für nachhaltige Erhaltung von obstgenetischen Ressourcen

Abstract

In Germany, all activities of long-term preservation, utilization, research and development of fruit genetic resources are based on the German National Program for Genetic Resources of Agricultural and Horticultural Plants. The preservation of fruit genetic resources is the basis for ensuring a sustainable fruit production in Germany. It has a long-lasting tradition, which reaches back to the early decades of the 20th century. Ever since, a multitude of cultivars of different fruit crop species is preserved in public and private germplasm collections. The German Fruit Genebank has been established as a decentralized network 10 years ago aiming at the coordination of the different germplasm collections in Germany to minimize the risk of losing fruit genetic resources. The German Fruit Genebank is organized in species-specific networks. Currently, six of those networks consisting of 41 different collections are held at federal and state governmental institutions as well as in communities and towns, non-governmental organizations, and by private individuals. Because of high priority, the first projects characterizing the genetic resources on trueness-to-type based on pomological and molecular characters were completed in the last few years. About 75% of the apple cultivars belonging to German Fruit Genebank and ~60% of the cherry cultivars could be determined as true-to-type. Based on the results exchange of plant material will be organized between the partners of the German Fruit Genebank in order to duplicate the cultivars within the established fruit-specific networks and fulfil the aim of the cooperation agreement. The German Fruit Genebank is represented at the web site www.deutsche-genbank-obst.de, including the database of the cultivars and accession data as focal point. Data from systematic characterization and evaluation along with photographs will be uploaded for all the cultivars preserved in this decentralized network.

Key words: decentralized network, fruit, genetic resources, German Fruit Genebank, preservation

Zusammenfassung

Das Nationale Fachprogramm zur Erhaltung und nachhaltigen Nutzung pflanzengenetischer Ressourcen landwirtschaftlicher und gartenbaulicher Kulturpflanzen ist die Arbeitsgrundlage aller Aktivitäten auf dem Gebiet der Erhaltung obstgenetischer Ressourcen in Deutschland. Die Erhaltung obstgenetischer Ressourcen, die in Deutschland bereits eine sehr lange Tradition hat und bis in die frühen Jahrzehnte des 20. Jahrhunderts zurückreicht, ist die Grundlage für eine langfristige Sicherung des Obstbaus. Bereits seit dieser Zeit wird eine Vielzahl an Sorten unterschiedlicher Obstarten in staatlichen und nichtstaatlichen Sammlungen erhalten. Die Deutsche Genbank Obst (DGO) wurde als dezentrales Netzwerk vor 10 Jahren mit dem Ziel gegründet, die Erhaltung verschiedener Sammlungen von genetischen Ressourcen zu

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Accepted
4 April 2019

koordinieren, um somit das Risiko eines Verlustes von Obstsorten zu minimieren. Die DGO besteht zum gegenwärtigen Zeitpunkt aus sechs obstartenspezifischen Netzwerken mit insgesamt 41 Sammlungen, die von Partnern sowohl an Bundes- und Landeseinrichtungen als auch in Landkreisen und Kommunen sowie von Vereinen und Privatpersonen erhalten werden. Da der Echtheitsüberprüfung der Obstsorten höchste Priorität beigemessen wird, war es in den letzten Jahren das Ziel, in den Sammlungen der Partner Bestimmungen der Sortenechtheit sowohl pomologisch als auch molekulargenetisch durchzuführen. 75% der Apfelsorten, die für die DGO ausgewählt wurden und ca. 60% der Kirschsorten konnten bisher als sortenecht bestimmt werden. Aufbauend auf diesen Ergebnissen wurde der erste Reiseraustausch zum Aufbau von Duplikaten in den Sammlungen organisiert, um das in den Kooperationsvereinbarungen gestellte Ziel, Erhaltung der Sorten an mindestens zwei verschiedenen Standorten mit jeweils mindestens zwei Bäumen, schrittweise zu erfüllen. Die Öffentlichkeitsdarstellung der DGO erfolgt über die Webseite www.deutsche-genbank-obst.de, wobei die Datenbank mit den Sorten- und Akzessionsdaten den Schwerpunkt des Internetauftrittes bildet. Zukünftig werden schrittweise Charakterisierungs- und Evaluierungsdaten sowie Fotos für alle Sorten der Sammlungen integriert.

Stichwörter: Deutsche Genbank Obst, Erhaltung, Genetische Ressourcen, Nationales Netzwerk, Obst

Introduction

For many centuries, fruit crops were mainly cultivated in abbeys, house gardens, and small farms of Central Europe (Morgan and Richards, 1993). At this time fruit production aimed to ensure the provision of fresh fruits and vitamins for self-consumption as long as possible over the year. This was not easy as long-term storage was still impossible. To overcome this problem fruits were processed into products, which could be stored more easily. On this account, fruit production was depending on the availability of a high number of cultivars differing in ripening time and properties for processing (e.g. backing, cooking, drying, winemaking, and distilling). Today, most fruit production takes place in highly specialized farms and the provision of a sufficient amount of fruits for fresh-consumption is not an issue anymore. Only a few number of top cultivars are produced globally at large quantities. Fruits of these cultivars are stored for months in high-tech storage facilities and imported from the Southern hemisphere when out of season in Europe, respectively. This has led to a dramatic loss of diversity in forms of traditional and locally adapted cultivars (Way et al., 1990). The global development of agricultural production has resulted in a worldwide loss of biodiversity, a problem that was first addressed by the United Nations (U.N.) when the Convention on Biological Diversity (CBD, https://www.cbd.int/convention/) was passed in Rio de Janeiro (Brazil) in 1992.

Since that time, the conservation of plant genetic resources (PGR) has gained significant importance and is now accepted as an essential responsibility of national governments (Engels, 2002). Several countries have strengthened efforts for the conservation and sustainable use of PGR based on the CBD and the Global Plan of Action for the Conservation and Sustainable Use of PGR for Food and Agriculture (http://www.fao.org/home/en/). Today, biodiversity is regarded as an important global issue. The Global Plan provides a coherent framework for activities in the field of *in situ* and *ex situ* conservation and for sustainable utilization of PGR. One of the actions determined in the Global Plan is the building of strong national programs, as they are the foundation of regional PGR efforts, as well as to promote international cooperation on access to PGR and the fair and equitable sharing of benefits arising from their use. In 2002, the first German National Program for Genetic Resources of Agricultural and Horticultural Plants was published, and updated in 2012 (http://www.ble.de/). This program provides an essential basis for conservation, utilization, research and development of genetic resources (cultivated plants and wild crop relatives) in agriculture and horticulture in Germany. The program also aims at the re-introduction of old varieties in meadow orchards, in breeding programs, in botanical gardens, and in landscape architecture. The gentle use of such genetic resources is the best way for ensuring a sustainable preservation.

One emphasis of the German National Program for Genetic Resources of Agricultural and Horticultural Plants is the establishment of a decentralized network for preservation of fruit genetic resources (FGR). Such a network was established in 2007. The present article provides information about the history and the initial situation of the government-organized preservation activities in Germany, the establishment of the German Fruit Genebank (GFG) as an efficient conservation strategy and the current state and ongoing activities of this network about 10 years after launching.

Conservation of Fruit Genetic Resources in Germany in the past

The preservation of FGR is the basis for ensuring a sustainable fruit production. It has a long-lasting tradition in Germany. First government-organized activities date back to the early decades of the 20th century. At this time, institutional collections were established at the Institute for Breeding Research of the Emperor-Wilhelm-Institute in Müncheberg (Germany) and the Biological Imperial Institute for Agriculture and Forestry in Naumburg (Germany). These collections mainly consisted of landraces, primitive forms and wild species as the basis for science-based fruit breeding (Höfer and Hanke, 2014). During the time of socialism in the former German Democratic Republic, the fruit breeding activities were centralized at the Institute for Fruit Research in Dresden-Pillnitz in 1971. The collections of Müncheberg and Naumburg

were integrated into these activities and extensive plant material was transferred to Dresden-Pillnitz to establish the still existing 'Fruit Genebank'. Extensive *ex situ* collections of cultivars and wild species belonging to several genera (e.g. *Malus, Pyrus, Prunus* and *Fragaria)* have been maintained in Pillnitz ever since. In 1991 after the German reunification, the Institute for Fruit Research was closed. Following re-organization, parts of the former institute became part of the Federal Institute for Breeding Research on Cultivated Plants, which belonged to the Federal Ministry of Food and Agriculture. The former group working on preservation of FGR in Dresden-Pillnitz was incorporated into the Institute for Plant Genetics and Research on Cultivated Plants with its headquarter in Gatersleben. However, the fruit collections and the working group remained as a branch office in Dresden-Pillnitz. In 2003, the responsibility for the FGR collections was re-transferred to the fruit breeding institute (current name: Institute for Breeding Research on Fruit Crops) in Dresden-Pillnitz, now belonging to the Julius Kühn-Institut (JKI), the Federal Research Centre for Cultivated Plants.

Since 2003, the 'Fruit Genebank' has focused its activities on maintenance and restructuring of the collections as well as on evaluation of the existing plant material. The 'Fruit Genebank' focuses on fruit species native to Central Europe and species which are important for fruit production in Germany in the present as well as in the past (Höfer and Hanke, 2014). This genebank contains approximately 4,500 accessions and maintains both cultivars of domesticated fruit species and their wild relatives. Safeguarding of the existing unique and valuable diversity of fruit germplasm is realized in an *ex situ* field collection on about 10 ha.

Beside this genebank numerous other collections of FGR exist in Germany, which belong to universities, other governmental institutions, districts and communes, non-governmental organizations, and private individuals (Flachowsky and Höfer, 2010). However, the risk of losing individual genotypes cannot be fully mitigated using such a decentralized and uncoordinated strategy for conservation. Some genotypes are present in several collections whereas others are present in only one or a few. Those genotypes are threatened with extinction. A gradual loss is expected when collection holders have to cease their activities (e.g. age-related, illness), as nobody knows about the current state of distribution of each individual cultivar formerly preserved in this particular collection. On this account, a new strategy for conservation was urgently need, which guarantees a good overview about the still existing diversity and gives detailed information about the distribution of individual genotypes.

Structure, strategic considerations and setup of a new way for conservation of FGR in Germany

The new structure

In order to achieve an efficient conservation strategy for FGR in Germany, the GFG was established. The GFG is a national decentralized genebank network for FGR, which is under central coordination. This network was built to ensure effective and long-term conservation and to ensure the availability of FGR for research and breeding. Furthermore, it provides information about pomological and landscaping traits. Both the regulatory and technical framework had to be elaborated in the beginning.

The GFG uses existing structures, capacities, personnel, and financial resources as efficiently as possible. The overall network is further divided into species-specific networks (e.g. apple network, strawberry network). The structure of the GFG is shown in Fig. 1. The aim is to establish such species-specific networks for all fruit species native to Central Europe and for species, which are and were important for German fruit production. Each network consists of the Information and Coordination Centre for Biological Diversity, the GFG coordination centre, the coordinator of the species-specific network and the network partners. A cooperation agreement was drawn up, which has to be signed by each partner. First cooperation agreements were signed in November 2007 already.

The **Information and Coordination Centre for Biological Diversity** of the Federal Office for Agriculture and Food has an advisory function and represents the GFG in international affairs. Furthermore, it integrates the data of the GFG into national and international databases for PGR. One of these databases is PGRDEU (https://pgrdeu.genres.de/), which is the main national inventory for PGR for food and agriculture in Germany.

On behalf of the German Federal Ministry of Food and Agriculture, the JKI, Institute for Breeding Research on Fruit Crops, has taken the role of the **Coordination centre**. The coordination centre is responsible for the further development of the GFG in general, for coordinating the work between the species-specific networks and for supervising the website and the national database of FGR (http://www.deutsche-genbank-obst.de/). The coordination centre gives advice to the coordinators of the species-specific networks to improve their work and consequently the quality of the national collection. Since January 2014 Dr. Monika Höfer coordinates the GFG.

The **coordinators of the species-specific networks** are responsible for organizing the cooperative work between the network partners and for the further development of the species-specific network. The network coordinators define the cultivars/genotypes, which should be preserved, they search for new partners (collection holders) and sign cooperation agreements with them. Finally, they are responsible for the species-specific part of the database.

Network partners can be federal or state governmental research institutions, districts, communes, clubs and non-governmental organizations. These partners undertake activities on a voluntary basis to maintain the FGR of their own collections. If possible, they contribute to the characterization, evaluation and documentation of FGR. Furthermore, the partners agree to send plant material

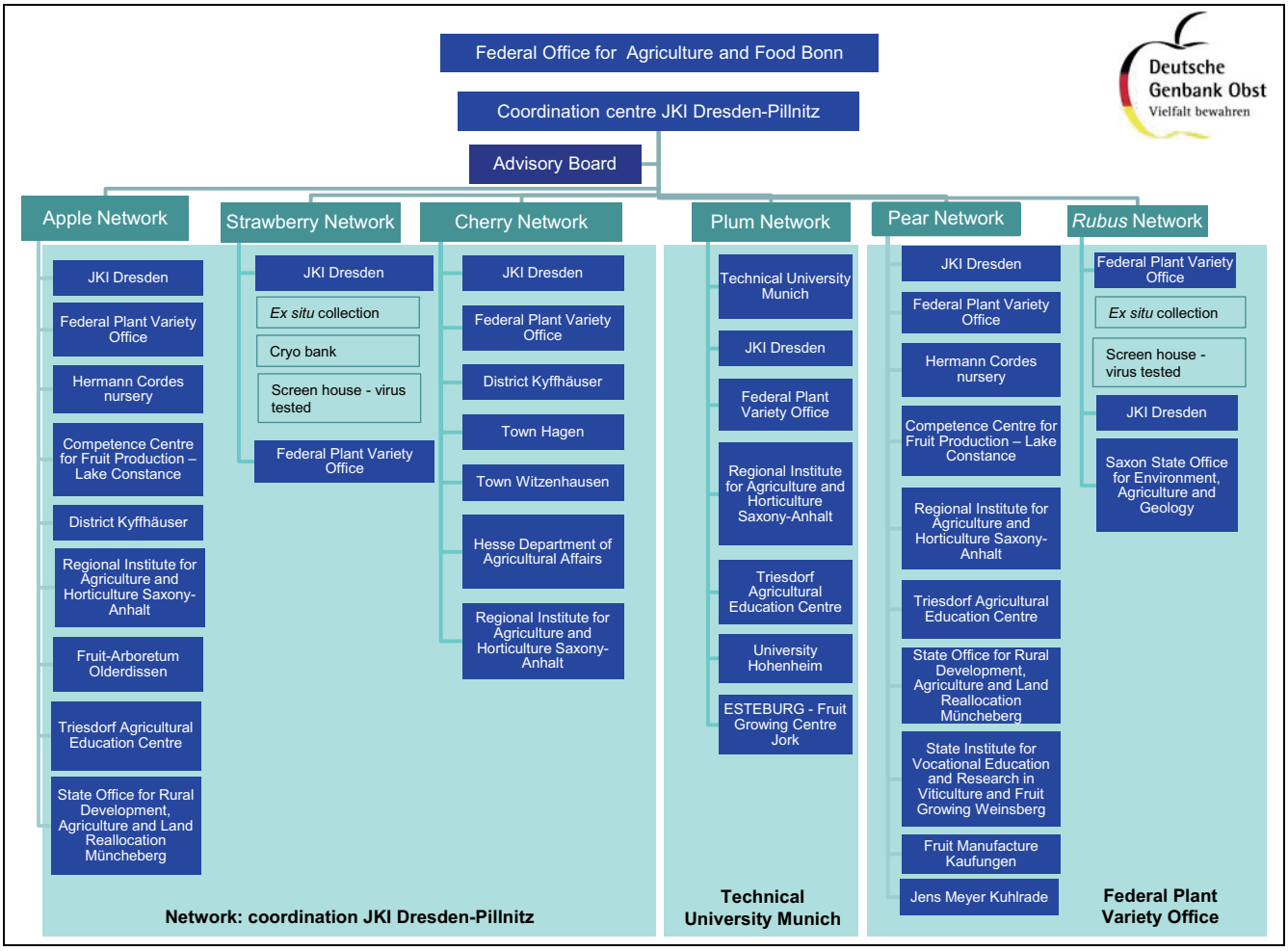

Fig. 1. Organization of the German Fruit Genebank (GFG). Current state of the network about 10 years after launching.

(e.g. bud wood or plants depending on the species) of their own collections to anyone who is interested. The network partners can present themselves as part of the network. They receive information and advertising material and they can use the GFG logo for their correspondence. Network partners can be collection holders with full rights and responsibilities or supporting partners, which support the work of the GFG. Supporting partners also have the right to use the GFG logo.

In addition to this general structure, the President of JKI appoints an Advisory board regularly for a period of five years. The advisory board has the duty to advise the coordination centre on questions about collection management, documentation and public relationship and sustainable use of FGR. The members of the advisory board are professional experts of agriculture and/or horticulture, members of non-governmental organizations like the German Pomological Society and the Nature and Biodiversity Conservation Union. At the annual meetings, the GFG coordination centre and the coordinators of the species-specific networks present the actual state of the development. Successive aims with respective to individual tasks are discussed.

Strategic considerations

Most fruit species are vegetatively propagated heterozygous crops. Therefore, maintaining the genetic diversity by means of specific genotypes, such as old landrace cultivars, is more demanding than for most inbred seed-producing plants. FGR are usually maintained *on farm* or in *ex situ* field collections (Fig. 2A-F). They are preserved in active collections where accessions of each genotype are available for comprehensive characterization, evaluation, and as stock material for further distribution. However, several disadvantages limit the efficiency of active collections and threaten their security. The genetic resources are always exposed to pests, diseases and to natural abiotic hazards (Peil et al., 2004). Back-up collections for these plant materials are necessary to provide security. A safety back-up collection comprises accessions of such an active collection at a different location (Engels and Visser, 2003), which can be a second field site, a greenhouse, or a culture stock maintained *in vitro* or in cryopreservation. Field genebanks require considerable inputs in the form of land, labour, management and materials, and therefore, their capacity to ensure the maintenance of the diversity representing the species is limited (Engelmann

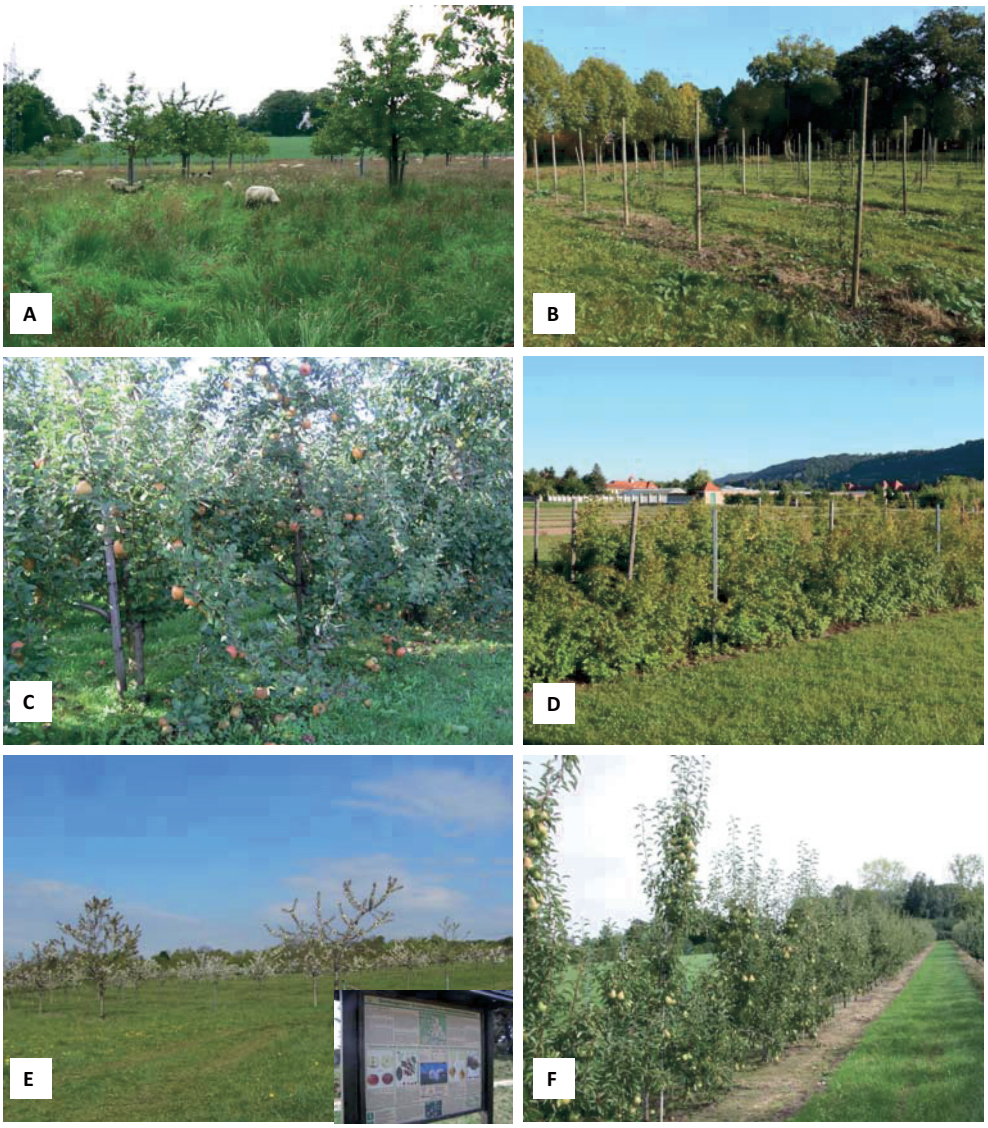

Fig. 2. Preservation of fruit genetic resources in the German Fruit Genebank (GFG) by partner institutions. **A**, *on farm* cherry collection located at Hagen a.T.W.; **B**, safety back-up field collection of plum located at the ESTEBURG – Fruit-growing Centre Jork; **C**, *ex situ* field collection of apple located at the Competence Centre for Fruit Production – Lake Constance; **D**, *ex situ* field collection of *Rubus* located at the Saxon State Office for Environment, Agriculture and Geology (Dresden-Pillnitz); **E**, *on farm* apple collection located at the Schlachtberg (Bad Frankenhausen, District Kyffhäuser; foto: PUSCH et al. 2002); **F**, *ex situ* field collection of pear located at the Federal Plant Variety Office (photo: Wurzen).

and Engels, 2002). Cryopreservation is one option to overcome these problems (at least in part). On this account, more attention will be paid to this form of preservation in the future.

The conservation strategy of the GFG stipulates that each cultivar has to be duplicated (at least) within the fruit-specific network. Therefore, each cultivar should be preserved in at least two collections located at different places in Germany with at least two trees per cultivar and collection. For each none-tree species like strawberry, a minimum number of individual plants has to be defined. For tree species, the network partners have agreed about a strategy for grafting. In one collection, the trees will be grafted onto dwarfing rootstocks, but in the second collection, they can be grafted onto dwarfing, semi-dwarfing or standard rootstocks. The selection of the rootstock depends on the individual aim of the respective network partner. Federal and state governmental research institutions commonly use dwarfing or semi-dwarfing rootstocks (Fig. 2B, 2C and 2F). Those collections will be used for characterization and evaluation. Collections hold by districts, communes, clubs or non-governmental organizations and private persons comprise cultivars usually grown on seedling rootstocks in landscape like old-fashioned orchards (*on farm* preservation). Good examples of *on farm* collections are located in Hagen a.T.W. (Fig. 2A; Braun-Lüllemann and Bannier, 2010) and at the Schlachtberg in the district Kyffhäuser, Thuringia (Fig. 2E). Traditional apple and cherry cultivars that are well adapted to the local soil and climatic conditions are considered for these collections.

Initial steps to set up the network

To set up the technical framework, the first step was to create an inventory of collections and the still existing varieties and cultivars in Germany. Based on the former register of fruit species in Germany, a research project entitled ‘Inventory-taking and documentation of fruit

genetic resources in Germany' was carried out in 2005 and 2006 by the Humboldt-University of Berlin and the State Environmental Agency of Brandenburg. The aim was the development and then the enlargement of the national catalogue of fruit species and cultivars, both *ex situ* and *in situ*. Altogether about 19,000 plants (≈ 14,000 *ex situ* and ≈ 5,000 *in situ*) of 50 species found at 409 locations were registered. Over 6,062 unique cultivars were identified, which belong to 30 native species (Flachowsky and Höfer, 2010).

Within the GFG, cultivars of native fruit species and fruit species important for current and former fruit production in Central Europe are preserved. The cultivar spectrum comprises (1) German cultivars including new German selections, (2) cultivars with a social cultural, local or historical relation to Germany and (3) cultivars with important pomological traits especially for breeders. Additional criteria for preservation are determined for each species-specific network and recorded in the cooperation agreement.

Current state and ongoing activities of the German Fruit Genebank

Preservation

Currently, six fruit species-specific networks exist with 20 partners and 41 collections: the apple network, with nine partners; the cherry and plum (*Prunus* spp.) network, each with seven partners; the Rubus network, with three partners; and the strawberry network, with two partners. The pear (*Pyrus* spp.) network started with ten partners in 2017 (Fig. 1). Based on the passport data of the cultivars, an expert group selected cultivars to be preserved within the particular fruit-specific network. Currently, 743 apple, 288 cherry, 209 plum, 239 strawberry, 42 Rubus and 204 pear cultivars were selected (Table 1). The lists of selected cultivars also include a number of older cultivars that are described in literature, but which are currently missing. Those cultivars are permanently searched to be included in the collections, as they represent an important part of our genetic diversity. Coordinator for the species-specific networks for apple, cherry and strawberry is the JKI, Institute for Breeding Research on Fruit Crops in Dresden-Pillnitz. Coordinator for plum is the Technical University Munich, whereas for pear and Rubus it is the Bundessortenamt (Federal Plant Varieties Office, Wurzen).

The apple network is the largest fruit-specific network. In this network, there are apple cultivars from different centuries. The oldest cultivars date back to the 12th century.

The situation of the plum network is problematic. The main reason is the Sharka or plum pox disease. Sharka is a quarantine disease caused by the Plum pox virus (PPV), which is a serious threat to plum production. The ESTEBURG – Fruit-Growing Centre in Jork in the North of Germany is located in a region where the occurrence and distribution of PPV is very limited. Therefore, this partner was chosen to establish the back-up collection. To guarantee a high phytosanitary status of the plant material before establishing this back-up collection, all bud wood materials were tested for PPV. The Technical University of Munich who is currently leading the plum network realized this. Only virus-free material was grafted onto the PPV hypersensitive rootstock 'Docera 6'. Based on the hypersensitive reaction of 'Docera 6' to PPV, infected buds cannot survive. Using this strategy virus-free plants of 38 cultivars were produced and planted into the back-up collection already.

The situation is also problematic for the Rubus network. Maintaining Rubus plants true-to-type in the field is not easy. Rubus plants can generate a prolific number

Table 1. Composition of the German Fruit Genebank (GFG), number of cultivars tested for trueness-to-of the type, the analysis of duplicates based on the records of the different partners in the database of the GFG in dependence on the fruit species.

Network	No. Cultivars	No. cultivars trueness-to-type tested	No. cultivars >= 3	No. cultivars = 2	No. cultivars = 1	No. cultivars = 0	% cultivars duplicated
Apple	**743**	558	319	134	208	82	**69**
Pear	**204**	23	59	24	32	89	**72**
Cherry							
Sour cherry	**52**	30	17	6	15	14	**61**
Sweet cherry	**236**	139	70	47	84	35	**58**
Plum	**209**	0	19	21	49	120	**45**
Strawberry	**239**	100	86	74	42	37	**79**
Rubus*	**42**	0	8	14	14	6	**61**

* The network Rubus contains the species raspberry, blackberry and loganberry.

Fig. 3. Preservation of genetic resources of strawberry in the German Fruit Genebank (GFG) at the Julius Kühn-Institut (Dresden-Pillnitz) and the Bundessortenamt (Federal Plant Variety Office, Wurzen). **A**, potted plants of the *ex situ* strawberry collection held at JKI Dresden-Pillnitz; **B**, facility for cryopreservation at JKI Dresden-Pillnitz; **C**, virus-free material of strawberry maintained in an insect-protected screen house at JKI Dresden-Pillnitz; **D**, *ex situ* field collection of strawberry at the Bundessortenamt Wurzen.

of suckers on their sprawling root system. On this account, care is to be taken to prevent cultivar mix-ups. Only three partners were found who agreed to collaborate in Rubus preservation. They selected cultivars, which belong to the species *R. idaeus*, *R. sectio Rubus*, *R. loganobaccus* or *R. hybrid*. Genetic resources of Rubus are held as bushes in the orchard (Fig. 2D), in an insect-protected screen house or as potted plants in the field.

For strawberry, there are only two *ex situ* collections in the network (Fig. 3). One is a collection of potted plants (Fig. 3A), whereas the second collection represents a traditional field planting (Fig. 3D). *Fragaria* spp. field plantings have specific challenges. A regular monitoring is necessary to avoid that runners spread between different accessions. Other challenges are the threat of naturally occurring viruses, and the necessity of periodic replanting. Ideally, strawberry germplasm should be kept as potted plants under insect-proof screens (Fig. 3C) with an active integrated pest management program to reduce the risk of virus contamination (Hummer, 1991). Flowers and fruits must be removed from the plants grown under screen, and active field collections must be established from virus-free plant material for characterization and evaluation. High costs and budget limitations do not allow further duplication of the *Fragaria* collection in the field. Maintaining the entire collection as duplicate under *in vitro* and *in vitro* cold storage conditions is also impossible (Höfer, 2011). Cryopreservation seemed to be the most promising alternative. A highly reproducible cryopreservation protocol combining vitrification with cold acclimation of donor plants was developed and efficiently applied (Höfer, 2016). Currently, long-term cryopreservation was initiated for 132 *Fragaria* cultivars, belonging to five species, with an average regrowth rate of 86% (Fig. 3B).

To implement the conservation strategy (duplication of selected cultivars) an exchange of plant material is regularly organized between the GFG partners. The exchange occurs only after testing the material on trueness-to-type based on pomological and molecular characters. The development of the GFG, the establishment of new fruit-specific networks, including further cultivars, and finding new network partners is a dynamic process.

Characterization

The comprehensive characterization and evaluation of FGR is essential for utilizing them in breeding and for future germplasm acquisition. It is also necessary for setting up maintenance priorities. The usefulness of genebanks is dependent upon their ability to provide sufficient carefully preserved accessions that are well-annotated (Walters et al., 2008). On this account, all accessions of the GFG have to be characterized and tested on trueness-to-type. This is done in a two-step procedure based on pomological and molecular characters.

First step is the characterization based on pomological characters. At least two experts, preferably members of the German Pomological Society, should perform the pomological characterization. First pomological characterizations were carried out in the apple and the cherry networks. For strawberry it was not possible with a comparable intensity and quality, as there are only a very few experts with a good knowledge about traditional cultivars available (Table 1). Second step of the characterization is a molecular DNA fingerprint analysis. Therefore, the European Collaborative Programme for Plant Genetic

Resources (ECPGR; http://www.ecpgr.cgiar.org/) working groups *Malus/Pyrus* and *Prunus* recommended a standard set of microsatellite (SSR) markers and a list of standard genotypes. Such a standardized procedure was suggested to allow comparisons of DNA fingerprinting results between different European collections in the future. For apple, 17 SSR markers were defined. Sixteen SSR markers were proposed for cherry (Clarke and Tobutt, 2009), whereas for strawberry 20 SSR markers are recommended (Horvath et al., 2011).

Within the first characterization projects, about 75% of the apple cultivars and 60% of the cherry cultivars could be confirmed as true-to-type (Table 1; Höfer et al., 2017). A comparable molecular characterization was performed by the Swiss Fruit Genetic Resources organization (Bühlmann et al., 2015). The marker data were also used to search for synonyms (identical genotype labelled with different names) and homonyms (different genotypes labelled by the same name). The identification of duplicates, mislabeled genotypes, synonyms, and homonyms assist in the efficient and sustainable management of the collections. The elimination of redundancies will increase the cost efficiency for existing collections, thus opening opportunities for preservation of novel accessions or accessions previously not recognized as unique.

The data sets from the above-described projects are currently implemented into international databases as reference sets for other national and international collections. The analyses on trueness-to-type serve only as a starting point. Further characterization is performed by studying the population structure and parent-offspring relationships. Examples can be found by Girichev et al. (2016) and Puskas et al. (2016).

For getting a much deeper insight into the genetic diversity of the preserved FGR in Germany SNP (Single Nucleotide Polymorphisms)-genotyping is performed as an additional step. This will allow performing very detailed studies on parent-offspring relationships and the detection of associations between genotype and phenotype. Studies on traits affecting the breeding efficiency like self-incompatibility are also performed (Schuster et al., 2007 and 2012).

Evaluation

For evaluation, several research projects are in progress, either at JKI or in GFG partner organisations. Evaluation is currently performed for a range of phenological, morphological and pomological traits either on fruits or at the tree/plant level (Höfer et al., 2012; Höfer and Peil, 2015). Therefore, descriptors of the Union for the Protection of New Varieties of Plants (UPOV) and FAO/Bioversity are used. Disease resistance traits are continuously studied by artificial inoculation in the greenhouse or under natural, unsprayed conditions in the field (Bestfleisch et al., 2014a, 2014b; Girichev et al., 2018; Kellerhals et al., 2012; Schuster and Tobutt, 2004).

In addition to the appearance and the sensory properties of fruits, the increased consumer awareness of potential health benefits from fruit consumption has increased. In this context, the quality analysis of the commercially relevant physicochemical fruit characteristics is becoming increasingly important. In various studies, antioxidative compounds were investigated in sour cherries (Grafe and Schuster, 2014) and phenolic profiles in plums (Treutter et al., 2012; Jaiswal et al., 2013; Goldner et al., 2015).

Characterization and evaluation of FGR should be extended in the future. More network partners and more cultivars that are traditional should be included. In the frame of ECPGR, several projects were started in the past few years. The aims of these projects were to include collaborative actions for updating, documenting and communicating the richness of FGR in the EU, and the use of common protocols and tools available for characterisation and evaluation. The JKI is with its cultivar collections network partner of all fruit-specific networks of the GFG and partner in the European research projects: PRUNDOC (Hjeltnes et al., 2017), EUCHERRY (Höfer and Giovannini, 2017) and the currently ongoing 'Pomefruit' and 'Prunus Alignment'.

Presentation and documentation

The GFG is presented at http://www.deutsche-genbank-obst.de/. Beside information about the structure and the partners with contact data, there are also the conditions for transfer of plant material available. The homepage provides access to the GFG database containing detailed information about the cultivars and the individual accessions. The database is part of the information of *ex situ* collections in Germany and includes this information into the National Inventory of Plant Genetic Resources (PGRDEU, https://pgrdeu.genres.de/). The structure of the GFG database is divided in two domains, an internal domain and a public domain.

The **internal domain** is subdivided into three levels. The first level is for the coordination centre and the coordinators of the species-specific networks. Authorized persons are allowed to assign respective rights to network partners. They are also allowed to add passport lists for appropriate fruit species. The passport data are documented according to the FAO/Bioversity multi-crop passport descriptors V.2.1. (2015). The second level is for person, who were authorized to act as coordinator of a network partner. This person is able to edit contact data of this partner and to assign rights for its internal co-workers (third level). In addition, this person is allowed to include the collections of this partner. Currently, 1,725 cultivars are defined as worthy to be preserved within the particular fruit-specific networks (Table 1). The upload of characterization and evaluation data of the cultivars including photos is still in progress.

Within the **public domain**, users are able to search for cultivars and accessions, to download cultivar information as pdf-sheets and to find all information on how to request for plant material (bud wood scion and strawberry plants). In 2017, 6,767 persons visited the website with a monthly average ranging between 707 and 1,056. This is an increase of about 70% compared to 2016. The visi-

tors from abroad were mainly from Hungary, Austria and Switzerland. The documents mostly downloaded are the material transfer agreements.

Beside its internet representation, the GFG provides any information about FGR in Germany (news, research results, data of events etc.) via the 'Journal of Cultivated Plants' which is edited by JKI. This is the most important way for network partners to introduce themselves, their organization, their aims and their collections. Altogether, 13 network partners have already used this option (Höfer, 2010; Mayr, 2010; Schulte, 2010; Sensen and Harrer, 2011; Pusch, 2012; Walther, 2012; Oetmann-Mennen, 2013; Bannier, 2014; Hadersdorfer and Treuter, 2014; Schnell, 2014; Braun-Lüllemann, 2015; Schlegel, 2015; Wackwitz, 2016). In addition, a summary of the results of the annual meeting of the Advisory Board and the processing status of the validation on trueness-to-type are published in this journal.

Furthermore, the GFG is regularly presented on several exhibitions to communicate the importance of the local or historical cultivars and their preservation as part of the cultural heritage of Germany. A special highlight was the participation of the GFG at the International Green week in Berlin on the occasion of 10th anniversary of the GFG in 2018. Sixteen co-workers from 11 network partners gave active support at the booth in the fair-hall of the Federal Ministry of Food and Agriculture of Germany (Höfer, 2018). A flyer of the GFG with the names of all networker partner institutions is available on the website. Those network partners, which are scientific institutions, use national and international meetings to communicate the aim and the results of this network.

Utilization

Use policy for FGR allows free access to any plant material as long as the cultivar is not covered by national or international protection and the phytosanitary requirements of the recipient can be met. GFG network-partners have agreed to send plant propagation material (e.g. bud wood or plants in case of none-tree species) of their own collections to anyone who is interested. Recipients wishing to use the material for research, breeding and education in food and agriculture are required to sign international agreements. The first agreement is the Standard Material Agreement (SMTA), which is based on the International Treaty (http://www.planttreaty.org/9. The second Agreement is to agree that the SMTA shall be applicable to the transfer of PGR for Food and Agriculture other than those listed in Annex I of the International Treaty on PGR for Food and Agriculture. *Prunus*, *Pyrus* and *Rubus* are not included in Annex I. For all other purposes, which must be declared by the recipients, the access is without further requirements. Detailed information about the access to plant material is given at the GFG website.

In addition to the delivery of propagation material, leaf material for DNA analysis and fruits for exhibition are regularly requested by research institutions, pomological organizations and private persons. Most requests can be fulfilled using the FGR preserved in the 'Fruit Genebank' of JKI in Dresden-Pillnitz. A first review about the delivery of material from the 'Fruit Genebank', its utilization in breeding research and breeding is given by Höfer and Hanke (2014). Examples for the use of FGR germplasm in breeding can be found by Neumüller et al. (2010), Treutter et al. (2012) and Schuster (2005, 2014).

Conclusions

The GFG is the result of the attempt to find a new way for preserving FGR in Germany by bringing existing activities, resources, knowledge and expertise together and motivate actors to collaborate in a decentralized network with central coordination. Twenty partners were found who agreed to maintain FGR of their own collections on a voluntary basis. These partners receive financial support to test their own accessions on trueness-to-type together in joint projects. They have access to a shared database, where they can manage and document all data of their own genetic resources. The database provides an excellent overview about still existing FGR in Germany and their current state of distribution. Based on this information, back-up collections can be established easily. The establishment of back-up collections is part of the conservation strategy, as GFG partners agreed to preserve each cultivar/genotype at least at two locations with a minimum of two trees (2–3 plants for none-tree species) per cultivar/genotype and collection. The development of the GFG, the existing collections and the establishment of new fruit-specific networks, as well as the characterization and evaluation, including the documentation of the data, are dynamic processes. The GFG contributes (i) to the sustainable preservation of FGR in Germany, (ii) to the preservation of biodiversity of fruit species, (iii) to ensure the availability of this plant material for distinct user purposes and (iv) to maintain a part of the cultural heritage of Germany. Within the last 10 years, the GFG has been developed to self-organizing and efficient system with significant contributions to the German National Program for Genetic Resources of Agricultural and Horticultural Plants.

References

Bannier, H.J., 2014: Obstarboretum Olderdissen (Bielefeld) - Private Obstsortensammlung seit 1995. Journal für Kulturpflanzen **66**, 255-256.

Bestfleisch, M., Luderer-Pflipfl, M. Höfer, E. Schulte, J.N. Wünsche, M.V. Hanke, H. Flachowsky, 2014a: Evaluation of strawberry (*Fragaria L.*) genetic resources for resistance to *Botrytis cinerea* Plant Pathology, DOI: 10.1111/ppa.12278.

Bestfleisch, M., K. Richter, A. Wensing, J.N. Wünsche, M.V. Hanke, M. Höfer, E. Schulte, H. Flachowsky, 2014b: Resistance and systemic dispersal of *Xanthomonas fragariae* in strawberry germplasm (*Fragaria* L.). Plant Pathology, DOI: 10.1111/ppa.12232.

Braun-Lüllemann, A., H.J. Bannier, 2010: Alte Süßkirschsorten – Genetische Vielfalt in den Kirschanbaugebieten Hagen am Teuteburger Wald und Witzenhausen. Deutsche Nationalbibliothek hhtp://dnb.d-nb.de.

Braun-Lüllemann, A., 2015: Mehr als rot und rund – Biodiversität alter Süßkirschsorten im Kirschanbaugebiet von Witzenhausen. Journal für Kulturpflanzen **67**, 79-82.

Bühlmann, A., J. Gassmann, A. Ingenfeld, K. Hunziker, M. Kellerhals, J.E. Frey, 2015: Molecular Characterisation of the Swiss Fruit Genetic Resources **57**, 29-34.

Clarke J.B., K.R. Tobutt, 2009: A standard set of accessions, mircosatellites and genotypes for harmonizing the fingerprinting of cherry collections for the ECPGR. Acta Horticulturae 814, 615-618.

Convention on Biological Diversity, 1992: https://www.cbd.int/convention/.

Deutsche Genbank Obst: http://www.deutsche-genbank-obst.de/.

Engelmann, F., J.M.M. Engels, 2002: Technologies and strategies for ex situ conservation. In: Engels, J. M. M., V. R. Rao, A. H. D. Brown, M. T. Jackson (eds.) Managing plant genetic diversity. CABI, Wallingford and IPGRI Rome, Italy, pp. 89-104.

Engels, J.M.M., 2002: Genebank management: an essential activity to link conservation and plant breeding. Plant Genetic Resources Newsletter **129**, 17-24.

Engels, J.M.M., L. Visser, 2003: A guide to effective management of germplasm collections. IPGRI Handbooks for Genebanks No. 6. International Plant Genetic Resources Institute, Rome, Italy.

European Cooperative Programme for Plant Genetic Resources (ECPGR): http://www.ecpgr.cgiar.org/.

FAO/Bioversity multi-crop passport descriptors V.2.1., 2015: https://www.bioversityinternational.org/e-library/publications/detail/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21/.

Food and Agriculture Organization on the United Nations (FAO), 1996: Global Plan of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture, http://www.fao.org/home/en/.

Flachowsky, H., M. Höfer, 2010: Die Deutsche Genbank Obst, ein dezentrales Netzwerk zur nachhaltigen Erhaltung genetischer Ressourcen bei Obst. Journal für Kulturpflanzen **62**, 9-16.

Goldner, K., S. Vio Michaelis, M. Neumüller, D. Treutter, 2015: Phenolic contents in fruit juices of plums with different skin colors. Journal of Applied Botany and Food Quality **88**, 322-326.

Girichev, V., M.-V. Hanke, A. Peil, H. Flachowsky, 2016: SSR fingerprinting of German *Rubus* collection and pedigree based evaluation on trueness-to-type. Genetic Resources and Crop Evolution **64**, 189-203.

Girichev, V., M. von Reth, M.V. Hanke, M. Höfer, E. Schulte, H. Flachowsky, 2018: Evaluation of *Rubus* genetic resources on their resistance to cane disease. Genetic Resources and Crop Evolution, DOI: 10.1007/s10722-018-0670-1.

Grafe, C., M. Schuster, 2014: Physicochemical characterization of fruit quality traits in a German sour cherry collection. Scientia Horticulturae **180**, 24-31.

Hadersdorfer, J., D. Treuter, 2014: Eröffnung des Netzwerks zur Erhaltung von Pflaumensorten in der Deutschen Genbank Obst. Journal für Kulturpflanzen **66**, 398-399.

Hjeltnes, S.H., D. Giovannini, M. Blouin, D. Benedikova, P. Drogoudi, M. Höfer, G. Lacis, V. Ognjanov, M. Lateur, J.M. Engels, L. Maggioni, 2017: PRUNDOC – a project to define accessions for the European Collection. Acta Horticulturae **1175**, 19-14.

Höfer, M., 2010: Partner der Deutschen Genbank Obst: Julius Kühn-Institut, Institut für Züchtungsforschung an gartenbaulichen Kulturen und Obst, Standort Dresden-Pillnitz. Journal für Kulturpflanzen **62**, 226-227.

Höfer, M., 2011: Conservation strategy of genetic resources for strawberry in Germany. Acta Horticulturae **908**, 421-429.

Höfer, M., 2016: Cryopreservation of in vitro shoot tips of strawberry by the vitrification method – Establishment of a duplicate collection of *Fragaria* germplasm. Cryo Letters **37**, 163-172.

Höfer, M., 2018: Die Deutsche Genbank Obst. Obstbau **4**, 259-260.

Höfer, M., R. Drewes-Alwarez, P. Scheewe, K. Olbricht, 2012: Morphological evaluation of 108 strawberry cultivars – and consequences for the use of descriptors. Journal of Berry Research 191-206.

Höfer, M., H. Flachowsky, M.V. Hanke, 2017: Sortenechtheitsprüfung in den Sammlungen der Deutschen Genbank Obst. Obstbau **8**, 496-498.

Höfer, M., D. Giovannini, 2017: Phenotypic Characterization and Evaluation of European Cherry Collections: A Survey to Determine the Most Commonly used Descriptors. Journal of Horticultural Science and Research **1** (1), 7-12.

Höfer, M., M.V. Hanke, 2014: 10 Jahre Obstgenbank Dresden-Pillnitz in der Verantwortlichkeit der Bundesforschung. Journal für Kulturpflanzen **66**, 117-129.

Höfer, M., A. Peil, 2015: Phenotypic and genotypic characterization in the collection of sour and duke cherries (*Prunus cerasus* and × *P. ×gondouini*) of the Fruit Genebank in Dresden-Pillnitz, Germany. Genetic Resources and Crop Evolution **62**, 551-566.

Horvath, A., J.F. Sánchez Sevilla, F. Punelli, R. Sesmero Carrasco, A. Leone, M. Höfer, P. Chartier, T. Barreneche, B. Denoyes, 2011: Structured diversity in octoploid strawberry cultivars highlights the importance of the old European germplasm. Annals of Applied Biology **158**, 358-371.

Hummer, K., 1991: *Fragaria* at the National Clonal Germplasm Repository at Corvallis, Oregon. In: A. Dale, J.J. Luby (eds.) The strawberry into the 21st century. Timber Press, Portland, OR, pp 106-107.

Jaiswal, R., H. Karaköse, S. Rühmann, K. Goldner, M. Neumüller, D. Treutter, N. Kuhnert, 2013: Identification of phenolic compounds in plum fruits (*Prunus salicina* L. and *Prunus domestica* L.) by high-performance liquid chromatography/tandem mass spectrometry and characterization of varieties by quantitative phenolic fingerprints. Journal of Agricultural and Food Chemistry **61**, 1202-31.

Kellerhals, M., M. Szalatnay, K. Hunziker, B. Duffy, H. Nybom, M. Ahmadi-Afzadi, M. Höfer, K. Richter, M. Lateur, 2012: European pome fruit genetic resources evaluated for disease resistance. Trees **26**, 179-189.

Mayr, U., 2010: Partner im Apfelnetzwerk der Deutschen Genbank Obst, das „Kompetenzzentrum Obstbau – Bodensee". Journal für Kulturpflanzen **62**, 57-58.

Oetmann-Mennen, A., 2013: Süßkirschen-Erhaltung in Hagen am Teutoburger Wald. Journal für Kulturpflanzen **65**, 429-432.

Morgan, J., A. Richards, 1993: The Book of apples. Brogdale Horticultural Trust in association with Ebury Press, London.

National Program for Genetic Resources of Agricultural and Horticultural Plants in Germany, 2012: https://www.ble.de/DE/Themen/Landwirtschaft/Biologische-Vielfalt/Nationales-Fachprogramm-Pflanzen/nationales-fachprogramm-pflanzen_node.html.

Nationales Inventar Pflanzengenetischer Ressourcen in Deutschland (PGRDEU): https://pgrdeu.genres.de/.

Neumüller, M., W. Hartmann, D. Treutter, 2010: Breeding for Sharka resistance and high fruit quality in European Plum (*Prunus domestica*) at Weihenstephan: breeding strategy and selection tools. Acta Horticulturae **874**, 221-228.

Peil, A., K. Richter, M. Höfer, M.V. Hanke, 2004: Beschreibung des Feuerbrandbefalls am Institut für Obstzüchtung in Dresden-Pillnitz im Jahr 2003. Erwerbs-Obstbau **46**, 141-148.

Pusch, J., W. Schuricht, U. Patek, G. Gramm, S. Reinicke, K. Rosenstock, 2002: Die Obstsorten im Kyffhäusergebirge. Veröffentlichungen Naturkundemuseum Erfurt. **21**, 103-121.

Pusch, J., 2012: Obstsorten-Erhaltungsgarten auf dem Schlachtberg bei Bad Frankenhausen (Kyffhäuserkreis, Thüringen). Journal für Kulturpflanzen **64**, 73-74.

Puskas, M., M. Höfer, R.A. Sestras , A. Peil, A.F. Sestras , M.V. Hanke, H. Flachowsky, 2016: Molecular and flow cytometric evaluation of pear (*Pyrus* L.) genetic resources of the German and Romanian national fruit collections. Genetic Resources and Crop Evolution **63**,1023-1033.

Schlegel, T., 2015: Das ZGT in Quedlinburg-Ditfurt – Ein junger Standort für das Versuchswesen und die Sortenerhaltung im Obstbau. Journal für Kulturpflanzen **67**, 262-263.

Schnell, S., 2014: Das Pomoretum Triesdorf ist das erste seiner Art. Journal für Kulturpflanzen **66**, 22-23.

Schulte, E., 2010: Das Bundessortenamt als Partner der Deutschen Genbank Obst (DGO). Journal für Kulturpflanzen **62**, 313-314.

Schuster, S., 2012: Incompatible (S-) genotypes of sweet cherry cultivars (*Prunus avium* L.). Scientia Horticulturae **148**, 59-73.

Schuster, M., 2014: Cultivars Resulting From Cherry Breeding in Germany. Erwerbs-Obstbau **56**, 67-72.

Schuster, M., H. Flachowsky, D. Köhler, 2007: Determination of self-incompatible genotypes in sweet cherry (*Prunus avium* L.) accessions and cultivars of the German Fruit Gene Bank and from private collections. Plant Breeding **126**, 533-540.

Schuster, M., K.R. Tobutt, 2004: Screening of Cherries for Resistance to Leaf Spot, *Blumeriella jaapii*. Acta Horticulturae **663**, 239-243.

Schuster, M., B. Wolfram, 2005: Sour cherry breeding in Dresden-Pillnitz. Acta Horticulturae **667**, 127-130.

Sensen, S., S. Harrer, 2011: Die Bundesanstalt für Landwirtschaft und Ernährung als Partner der Deutschen Genbank Obst (DGO) Journal für Kulturpflanzen **63**, 345-346.

Wackwitz, H.D., 2016: Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie. Journal für Kulturpflanzen **68**, 273-274.

Standard Material Agreement (SMTA) of the International Treaty: http://www.planttreaty.org/9.

Treutter, D., D. Wang, M.A. Farag, G.D. Baires, S. Rühmann, M. Neumüller, 2012: Diversity of Phenolic Profiles in the Fruit Skin of *Prunus domestica* Plums and Related Species. Journal of Agricultural and Food Chemistry **60**, 12011-12019.

Walther, E., 2012: Der Süßkirschenanbau in der Region Witzenhausen. Journal für Kulturpflanzen **64**, 482-483.
Walters, C., M. Gayle, C.M. Richards, 2008: Genebanks in the post-genomic age: Emerging roles and anticipated uses. Biodiversity **9**, 68-71.
Way, R.D., H.S. Aldwinckle, R.C. Lamb, A. Rejman, T. Sansavini, T. Shen, R. Watkins, M.N. Westwood, Y. Yoshida, 1990: Apples (*Malus*). In: J. N. Moore and R. Ballington (eds.) Genetic resources of temperature fruits and nuts. International Society of Horticultural Science, Leuven, Belgium, pages 1-62.