GLOBAL STRATEGY FOR THE CONSERVATION AND USE OF EGGPLANTS

With support from

CROP TRUST

The International Treaty ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Federal Ministry of Food and Agriculture

COVER PHOTO
Brinjal eggplant. Photo: World Vegetable Center

DISCLAIMER
This report aims to provide a framework for the efficient and effective ex situ conservation of globally important collections of eggplants. The Crop Trust considers this document to be an important framework for guiding the allocation of its resources. However, the Crop Trust does not take responsibility for the relevance, accuracy or completeness of the information in this document and does not commit to funding any of the priorities identified. This strategy document (dated 2 May 2022) is expected to continue to evolve and be updated as and when circumstances change or new information becomes available.

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Appendix 2 of this document provides a summary of a recent report: "The plants that feed the world: baseline information to underpin strategies for their conservation and use." That study was produced as a collaboration led by the Secretariat of the Plant Treaty, and involving the Alliance of Bioversity, the International Center for Tropical Agriculture (CIAT) and the Crop Trust, funded by the Norwegian Agency for Development Cooperation (NORAD, Government of Norway).

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The Crop Trust, Bonn, Germany, https://www.croptrust.org

Project coordinator at the Crop Trust: Peter Giovannini

ACRONYMS

AARNET	ASEAN – AVRDC Regional Network on Vegetable Research and Development
AEGIS	A European Genebank Integrated System
AFLP	amplified fragment length polymorphism
AMV	alfalfa mosaic virus
ASEAN	Association of Southeast Asian Nation
AVBC	Africa Vegetable Breeding Consortium
AVRDC	Asian Vegetable Research and Development Center
BLE	Federal Office for Agriculture and Food, Germany
BMEL	Federal Ministry of Food and Agriculture, Germany
Bt	*Bacillus thuringiensis*
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CGN	Center for Genetic Resources, the Netherlands
CKD	Crop Knowledge Database
CSIR	Council for Scientific and Industrial Research, Ghana
CWR	crop wild relatives
C&E	characterization and evaluation
DAR	Department of Agricultural Research, Myanmar
DNA	deoxyribonucleic acid
DOA	Department of Agriculture, Thailand
ECPGR	European Cooperative Programme for Plant Genetic Resources
EKP	Eggplant Knowledge Platform
FAO	Food and Agriculture Organization of the United Nations
G2P-SOL	Linking genetics resources, genomes and phenotypes of solanaceous crops (a Horizon 2020 project)
GRIN	Germplasm Resources Information Network
GP1	primary genepool
GP2	secondary genepool
GP3	tertiary genepool
GBIF	Global Biodiversity Information Facility
ICABIOGRAD	Indonesian Center for Agricultural Biotechnology Research and Development
ICAR	Indian Council of Agricultural Research
INRAE	Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement, France
IPGRI	International Plant Genetic Resources Institute (now Bioversity International)
IPK	Leibniz Institute of Plant Genetics and Crop Plant Research
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
MAGIC	multiparent advanced generation intercross
NARO	National Agriculture and Food Research Organization, Japan
NGO	Non-governmental organization
NORAD	Norwegian Agency for Development Cooperation
NBPGR	National Bureau of Plant Genetic Resources, India
NUS	neglected and underutilized species
QTL	quantitative trait loci
RAPD	random amplified polymorphic DNA
RBG	Royal Botanic Gardens
RFLP	restriction fragment length polymorphism
RNA	ribonucleic acid
SADC	Southern African Development Community
SMTA	Standard Material Transfer Agreement
SNP	single nucleotide polymorphism
SOP	standard operating procedure
SSR	simple sequence repeat
UPOV	International Union for the Protection of New Varieties of Plants
USD	United States dollar
USDA	United States Department of Agriculture
VIR	N.I. Vavilov All-Russian Institute of Plant Genetic Resources
WorldVeg	World Vegetable Center
WIEWS	World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture

Solanum melongena illustration from Seikei Zusetsu. Photo: Leiden University Library

Eggplant diversity Photo: WorldVeg

EXECUTIVE SUMMARY

Common eggplant (*Solanum melongena* L.), also known as brinjal eggplant or aubergine, is a vegetable crop grown for its large soft fruits which are used in cooking. There are also two African eggplant species grown locally: scarlet eggplant (*Solanum aethiopicum* L.) and gboma eggplant (*Solanum macrocarpon* L.). According to the statistics of the United Nations Food and Agriculture Organization (FAO), eggplant is grown on 1.8 million hectares (ha) globally, and 90% of eggplant production takes place in Asia. Breeding and research on eggplant is carried out in many countries. Numerous germplasm collections of eggplant and its related species exist to provide plant materials for breeding and related research.

In the present study, we overview the current status of eggplant germplasm conservation efforts and the use of eggplant diversity with the aim of providing a forward-looking strategy document. To do this, we surveyed the global databases Genesys and WIEWS (World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture) to obtain information about existing eggplant *ex situ* collections. The most often represented species in these databases is brinjal eggplant with 12,715 accessions conserved in total. This is followed by scarlet eggplant (886 accessions) and gboma eggplant (209 accessions). Wild relatives of eggplant are conserved in some collections, but some species are not well represented.

In total, 109 eggplant collection holders were identified through the database searches. The collection holders were asked to complete an online survey on the status of their collections and the challenges that they faced. Responses were received from 32 collection holders, 27 of which provided sufficient data for further analyses. Most of the collection holders that responded were governmental organizations or publicly funded institutions. Two respondents were non-governmental organizations (NGOs). Several challenges related to the sustainability of eggplant conservation and use were identified. Shortages of funds and staff were reported as major threats to collection viability and security by many of the collection holders. Opportunities for improvement included recruiting new and/or young people interested in eggplant conservation, and increased collaborations across national borders and among institutions. Improved documentation of existing plant materials and increased information sharing were also identified as areas for improvement.

The objective of this project is to outline an effective strategy to conserve the crop diversity of eggplant and its wild relatives. This global strategy suggests several key objectives for the coming years:

1. Continue to develop and broaden existing international collaboration efforts regarding the curation and conservation of eggplant genetic resources.
2. Facilitate the sharing of collection information among genebanks using a common Eggplant Knowledge Platform (EKP).
3. Facilitate the regeneration and safety duplication of existing collections in collaboration with research institutions, the plant breeding industry, private sector seed companies, and others.
4. Work with collection holders to complete/correct passport data in order to facilitate gap analysis and the identification of unwanted duplicate holdings.
5. Preserve crop wild relatives (CWR) and valuable pre-breeding material.
6. Further develop an international support system for collection holders that are facing significant technical and/or financial constraints to their conservation activities.

Pruning *S. incanum*. Photo: Maarten van Zonneveld

ABOUT THIS STRATEGY

The Crop Trust initiated the development of a global conservation strategy for eggplants to overview the current status and identify issues of concern.

This document is based on:

- A review of relevant scientific literature;
- Database searches and a stakeholder survey on *ex situ* collections; and
- Communication with stakeholders and collection holders.

The process was initiated in May 2021. First, searches of Genesys and WIEWS identified 109 collections containing eggplant genetic resources. Searches of Web of Science and communication with scientific experts identified other institutions conducting eggplant breeding and/or research.

A survey was developed (Appendix 3) and sent to all collection holders for which contact details were available. Thirty-two collection holders responded to the survey, and their responses were analyzed and compared with existing data and other general information. Genesys and WIEWS were used to develop an overview of existing *ex situ* collections and for further analyses. In addition, our analyses included information provided by the holding institutes.

During the compilation of this strategy, e-mail exchanges and meetings with key individuals took place. This global strategy should therefore be seen as experts opinions of stakeholders needs and priorities for the conservation and use of eggplant genetic resources.

The strategy document is divided into four main chapters:

- Chapter 1 provides background information based on a literature review with basic information from Taher et al. (2017) and Rakha et al. (2021), but updated.
- Chapter 2 describes the current ex situ collections based on data obtained from WIEWS and Genesys.
- Chapter 3 summarizes the results from our survey on eggplant conservation and use.
- Chapter 4 presents recommendations.

CONTENTS

Varieties of eggplant, c. 1870.
Chromolithograph by H. Briscoe.

1 BACKGROUND RESEARCH AND LITERATURE REVIEW

1.1 Brief introduction to cultivated eggplants

Common eggplant (*Solanum melongena* L.), also known as aubergine, brinjal eggplant or eggplant, is a warm season crop mainly cultivated in tropical and subtropical climates. Brinjal eggplant and *S. melongena* will be used interchangeably in this report. Two other cultivated eggplant species, scarlet eggplant (*Solanum aethiopicum* L.) and gboma eggplant (*Solanum macrocarpon* L.), have local importance in Africa (Daunay and Hazra, 2012). All three species are annual plants that produce typically large fleshy fruits which are eaten fried or boiled and are often mixed with spices, oil, meat or other vegetables.

Brinjal eggplant is grown worldwide but is especially popular in Asia and the Mediterranean. The crop is rich in bioactive compounds (Raigón et al., 2008; Plazas et al., 2014a). Brinjal eggplant is ranked among the top ten vegetables in terms of oxygen radical absorbance capacity (Cao et al., 1996) with high levels of phenolic acids in the fruit flesh and anthocyanin in the fruit skin (Plazas et al., 2013; Stommel et al., 2015). Such compounds have antioxidant activity and are known to have multiple beneficial health properties (Plazas et al., 2013; Braga et al., 2016).

Brinjal eggplant is an important vegetable, but there are challenges in its production, and yield losses often occur. Extreme temperatures, drought or flooding can affect the plants productivity and damage the fruits. Pests and diseases are also major constraints, especially in developing countries (Daunay and Hazra, 2012).

Because of its long growth period and its large and soft fruits, brinjal eggplant is vulnerable to a broad range of pests and diseases. Intensive spraying for pest control is common but this can result in health hazards and environmental damage issues (Srinivasan, 2009). Therefore, the development and use of improved and resistant varieties are important to support sustainable production. The development of varieties improved for climate adaptation and abiotic stress tolerance is also important.

1.2 Taxonomy and domestication

1.2.1 Phylogenetic relationships

The three cultivated eggplant species belong to the Solanaceae (nightshade) family, in which *Solanum* is the largest genus with approximately 1500 species (Frodin, 2004). Most *Solanum* taxa have a basic chromosome number of n=12 (Chiarini et al., 2010). In addition to eggplant, this genus includes other globally important crops such as potato (*S. tuberosum* L.), tomato (*S. lycopersicum* L.), minor crops including leafy nightshades (e.g. *S. scabrum* Mill. and *S. americanum* Mill.), and fruit-producing species including naranjilla (*S. quitoense* Lam.), melon pear (*S. muricatum* Aiton) and cocona (*S. sessiliflorum* Dunal). The taxonomy can be complex as different taxonomic levels exist and there are many synonyms; for details, see the Solanaceae Source.

The genus *Solanum* is diverse and can be divided into sub-genera. Eggplant belongs to the large and taxonomically challenging sub-genus *Leptostemonum* (Levin et al., 2006; Knapp et al., 2013; Vorontsova et al., 2013; Vorontsova and Knapp, 2016). This group is also informally termed 'spiny *Solanum*' because of the sharp prickles that are often present on stems and leaves. The taxonomic structure and phylogenetic relationships among species are intricate. The *Leptostemonum* sub-genus contains around 450 species distributed worldwide, and includes an Old World group with approximately 80 species, a New World group with approximately 250 species and an Australian group with approximately 120 species (Vorontsova and Knapp, 2012; Knapp et al., 2013). There are three clades in the Old World group: the Eggplant clade, the Anguivi clade and the Other Old World clade (Syfert et al., 2016).

The Eggplant clade includes brinjal eggplant (*S. melongena*) and its closest wild ancestor, *S. insanum* L., as well as nine other wild relatives: *S. agnewiorum* Voronts., *S. aureitomentosum* Bitter, *S. campylacanthum* Hochst. ex A. Rich, *S. cerasiferum* Dunal, *S. incanum* L., *S. lichtensteinii* Willd., *S. linnaeanum* Hepper & P.-M.L.Jaeger., *S. rigidum* Lam. and *S. umtuma* Voronts. & S.Knapp (Syfert et al., 2016).

The Anguivi clade includes the cultivated scarlet eggplant (*S. aethiopicum*) and the gboma eggplant (*S. macrocarpon*), as well as more than 30 related species. *Solanum anguivi* Lam. and *S. dasyphyllum* Schum. are the closest ancestors of scarlet eggplant and gboma eggplant, respectively (Lester, 1986; Lester and Daunay, 2003; Lester et al., 2011). Species in the Anguivi clade are somewhat distantly related to brinjal eggplant, but harbor resistance traits that have potential use in breeding programs for the improvement of both brinjal and scarlet eggplant.

The Other Old World clade includes another 35 species, seven of which are mentioned in the following chapters as potential crop wild relatives (CWR) of eggplants.

An eggplant diversity tree was developed as part of our literature survey and is available in Genesys. A diversity tree stratifies a genepool into groups and subgroups, a concept initially proposed by van Treuren et al. (2009). On the basis of further analyses, we estimated the number of accessions at the global level corresponding to each end-group in the eggplant diversity tree, and identified groups that are not well represented in collections. The results of these analyses highlight the high proportion of accessions in the eggplant genepool with an unknown biological status (wild, cultivated, or breeding material) recorded in Genesys and WIEWS (World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture) (see section 2.4), and also which CWR are not well represented in *ex situ* collections (see section 2.5).

1.2.2 Domestication

Solanum melongena was domesticated in Asia from *S. insanum*, a species that is widely distributed in tropical Asia from Madagascar to the Philippines (Knapp et al., 2013). Vavilov (1951) linked brinjal eggplant to an Indo-Chinese center of origin. A more recent study suggests three independent domestications of the crop, specifically in India, China and the Philippines (Meyer et al., 2012). Eggplant cultivation spread eastward to Japan and westwards along the Silk Road from the 8th century CE onwards. In the 14th century, Arab traders brought the plant to Africa and Europeans thereafter introduced it into the Americas and other parts of the world (Prohens et al., 2005). Scarlet eggplant and gboma eggplant were both domesticated in Africa from their wild ancestors, i.e., *S. anguivi* (Lester and Niakan, 1986) and *S. dasyphyllum*, respectively (Bukenya and Carasco, 1994).

1.2.3 Eggplant genepools

The wild relatives of eggplant can be classified on the basis of their ability to cross with cultivated species (i.e., the genepool concept) into primary (GP1), secondary (GP2) and tertiary genepools (GP3) (Harlan and de Wet, 1971). The GP1 of brinjal eggplant (*S. melongena*) includes its closest wild ancestor *S. insanum* (Plazas et al., 2016; Ranil et al., 2017).

Although brinjal eggplant is regarded as having an Asian origin, most of the genepool species are in Africa (Weese and Bohs 2010). The wild relatives are interesting as they may serve as sources of useful traits in breeding programs including those related to climate adaptation, resistance to pests and diseases and the presence of bioactive compounds (Meyer et al., 2015; Rotino et al., 2014). Such wild relatives produce small and bitter fruits and the plants are generally very spiny – both are undesirable traits. Hybrids between the three cultivated eggplants and their respective closest wild ancestors are fully fertile (Lester and Thitai, 1989; Bukenya and Carasco, 1994; Plazas et al., 2016). Eggplant also has many wild relatives that are generally cross compatible (Vorontsova et al., 2013; Syfert et al., 2016).

According to the Harlan and de Wet CWR Inventory, the GP2 of brinjal eggplant includes many species that are also phylogenetically close to brinjal eggplant. However, the taxonomic and phylogenetic relationships of these can be convoluted (Vorontsova et al., 2013). Knapp et al. (2013) suggested an eggplant complex that includes the cultivated brinjal eggplant (*S. melongena*) and nine wild species (see description of the Eggplant clade above). This was based on cross-compatibility and biosystematics data. The success of hybridizations between these taxa and the viability of hybrids is affected by reproductive barriers as reported for *S. dasyphyllum*, *S. linnaeanum* and *S. tomentosum* L. (Rotino et al., 2014; Kouassi et al., 2016).

The GP3 of brinjal eggplant includes yet more distantly related species (e.g., *S. torvum* Sw., *S. elaeagnifolium* Cav. and *S. sisymbriifolium* Lam.). Advanced breeding techniques are required for successful hybridization of these (Kouassi et al., 2016; Plazas et al., 2016; Syfert et al., 2016). The GP3 genepool contains many species that are potentially interesting, but are also particularly challenging, to use in a breeding program.

A CWR inventory compiled by Vincent et al. (2013) suggested the following 18 priority taxa for the brinjal eggplant genepool: *S. aculeatissimum* Jacq., *S. anguivi*, *S. anomalum* Thonn., *S. asperolanatum* Ruiz & Pav., *S. campylacanthum* Hochst. Ex A. Rich, *S. cumingii* Dunal, *S. grandiflorum* Ruiz & Pav., *S. incanum*, *S. insanum*, *S. lidii* Sunding, *S. linnaeanum*, *S. macrocarpon*, *S. marginatum* L. f., *S. rubetorum* Dunal, *S. sisymbriifolium*, *S. tomentosum*, *S. torvum* and *S. violaceum* Ortega.

Some of the genepool species can be used as food plants. They are often rich in micronutrients and may have regional importance, especially in Africa. Species in this category include *S. torvum*, *S. scabrum, S. americanum, S. quitoense* and *S. sessiliflorum*. Leafy nightshade (*S. scabrum*) is a popular African leafy vegetable (Yuan et al., 2019; 2020). Naranjilla (*S. quitoense*) is native to the Andes and national breeding activities with this species in Colombia and Ecuador are selecting high-yielding lines as scions and to identify CWR with disease resistance that can be used as eggplant rootstocks (Viera et al., 2019). *Solanum torvum* is important in local dishes such as Thai curries and is also used as a rootstock for tomato.

1.3 Production and geographic distribution of eggplant crops

Worldwide, eggplants are produced across an area of 1.8 million hectares (ha) (FAOSTAT 2021). Asia accounts for more than 90% of global eggplant production on a weight basis. China produces more than 50% (35.5 million tons) of the global eggplant crop, followed by India (30%, 12.7 million tons), Egypt (1.2 million tons) and Turkey and Iran (Table 1.1.). Other Asian countries such as Indonesia, Japan and the Philippines are also major eggplant producers. Aside from Egypt, the important eggplant-producing countries in Africa are Algeria, Ivory Coast and Sudan. The largest eggplant producers in Europe are Italy and Spain, followed by Romania, Ukraine, Greece, the Netherlands and France. In the Netherlands, eggplants are mainly

Table 1.1. Countries with more than 1000 ha under brinjal eggplant cultivation in 2019. Within each region, countries are listed from largest to smallest production area (in ha), with production (in tons) and productivity (tons/ha).

Region	Country	Area (ha)	Production (tons)	Average yield (tons/ha)
Africa	Egypt	43,818	1,180,240	26.9
	Sudan	21,180	94,592	4.5
	Côte d'Ivoire	20,491	103,757	5.1
	Ghana	6295	55,092	8.8
	Algeria	6047	184,145	30.5
	Mali	5591	81,644	14.6
	Rwanda	5145	27,978	5.4
	Morocco	2409	68,266	28.3
	Malawi	1000	29,911	29.9
Latin America	Dominican Republic	4282	27,821	6.5
	USA	2614	105,302	40.3
	Mexico	2333	185,234	79.4
	Venezuela	1789	20,348	11.4
	Guyana	1159	49,212	42.5
Asia & Oceania	China	781,695	35,555,562	45.5
	India	727,000	12,680,000	17.4
	Indonesia	43,954	575,392	13.1
	Turkey	23,337	822,659	35.3
	Philippines	21,819	249,890	11.5
	Iran	21,350	670,158	31.4
	Sri Lanka	9877	134,863	13.7
	Iraq	8660	136,749	15.8
	Japan	8650	301,700	34.9
	Pakistan	8566	89,724	10.5
	Syria	8342	154,807	18.6
	North Korea	5519	48,779	8.8
	Kazakhstan	4812	108,065	22.5
	Azerbaijan	4263	81,479	19.1
	Jordan	1792	55,630	31.1
	Saudi Arabia	1734	50,344	29.0
	Lebanon	1431	31,625	22.1
	Israel	1324	49,154	37.1
	Taiwan	1286	34,874	27.1
	Georgia	1071	4400	4.1
	Palestine	1015	48,490	47.8
Europe	Ukraine	5200	66,420	12.8
	Spain	3470	245,150	70.6
	Romania	4810	79,660	16.6
	Italy	9550	300,620	31.5
	Greece	1350	54,910	40.7
	Albania	1190	31,122	26.2

Source: FAOSTAT (2021)

grown in greenhouses. In the Americas, Mexico is the largest producer, followed by the USA. All the above values are expressed as total production (in tons) per country. However, if the production area and productivity per ha are considered, the picture changes somewhat. In Table 1.1., countries in each global region (e.g., Africa) are listed in order from largest to smallest area under eggplant production. The productivity in terms of yield per unit area is very low in some countries (approximately 5 tons/ha in some African countries) and very high in others (>70 tons/ha in Mexico and Spain). The productivity in China is very high, with average yields of approximately 45 tons/ha. Figure 1.1 shows the average annual eggplant production between 2010 and 2019, in tons, globally and in the top 10 eggplant-producing countries.

1.4 Cultivar groups and diversity studies

1.4.1 Cultivar groups and their characteristics

Brinjal eggplant (*S. melongena*) shows great morphological diversity and has been divided into four informal taxonomic/cultivar groups (groups E, F, G and H) (Lester and Hasan, 1991). Groups E and F contain very prickly wild or weedy lines that are primarily found in India and Southeast Asia. These are now classified as *S. insanum* (Ranil et al., 2017). Group G contains primitive *S. melongena* cultivars and landraces with small fruits and prickly leaves or stems. Group H consists of *S. melongena* lines that are less prickly than those in the other groups, as well as large-fruited landraces and modern cultivars (Daunay et al., 2001; Weese and Bohs 2010; Knapp et al., 2013).

Cultivars are also grouped on the basis of geographical information. Brinjal eggplant (*S. melongena*) cultivars are grouped into either Oriental (from southern and eastern Asia) or Occidental (from the Mediterranean area, Northern Africa and the Middle East) types, based on genetic and morphological characters (Hurtado et al., 2012; Cericola et al., 2013). A third group is miniature eggplant (also referred to as Italian type, cherry eggplant or finger eggplant).

Occidental eggplants typically produce fruits that are oval or elongated, are relatively large (200–600 g) and are most often dark purple. Oriental eggplants produce fruits in a range of colors (purple, violet, green) and with or without stripes. The fruits may be round or long and slender in shape. They often have a sweet flavor and are tender with a thin skin. In China, the preferred cultivars produce long fruits in a range of colors. In Japan, large and firm fruits are popular. The fruits can be long or egg-shaped, and they come in a range of colors. In Thailand, small fruits (<40 g), either round or very long, are popular. In India, eggplants with a range of sizes, shapes and colors are available. Miniature eggplants are small, narrow or rounded, sweet in taste, have a tender texture and a thin skin, and come in a range of colors.

Scarlet eggplant (*S. aethiopicum*) can be classified into four informal cultivar groups: gilo, shum, kumba and aculeatum. These cultivar groups are differentiated based on morphological characteristics and plant use (Lester, 1986). The gilo cultivars produce edible fruits with a range of different shapes, colors and sizes. The leaves are hairy and inedible. Shum cultivars produce inedible fruits, but have small, glabrous, edible leaves. Kumba cultivars produce edible fruits and leaves. The fruits are large and flat and the leaves are glabrous. Aculeatum cultivars are grown as ornamental plants. They are pricklier than those in other groups and

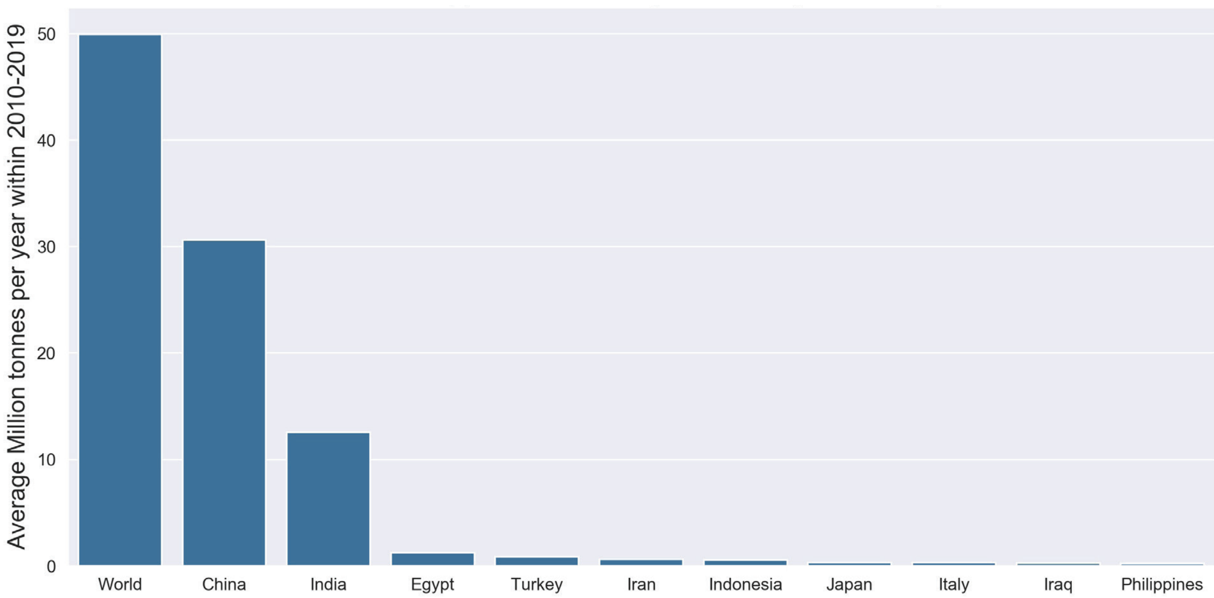


Figure 1.1 Average eggplant production (million tons per year) globally and in the top 10 eggplant-producing countries (2010–2019). Data source: FAOSTAT (2021)

produce flat fruits (Lester 1986; Prohens et al., 2012; Plazas et al., 2014b).

The African gboma eggplant (*S. macrocarpon*) and forest bitterberry (*S. anguivi*) have no recognized cultivar groups, although both species show great phenotypic diversity and produce edible fruits and leaves (Plazas et al., 2014b).

1.4.2 Phenotypic diversity studies

As noted above, the fruits of eggplants exhibit phenotypic variation in color, shape, texture and size. Vegetative traits, such as leaf size and number and plant form/growth habit, also vary widely. Modern varieties are bred to be uniform and stable, in contrast to landraces and wild eggplants that show high phenotypic diversity within their populations. Round-fruited cultivars are often more diverse than semi-long or long-fruited cultivars (Prohens et al., 2005). There is also high levels of phenotypic diversity within and among different variety groups and between modern varieties.

Genebanks provide information about phenotypic characters at the accession level. This information often includes plant growth habit, branching pattern, characteristics of leaves, flowers, and fruits, plant height, and flowering and fruit maturation time (Taher et al., 2017). For example, among materials held in the WorldVeg collection (see Chapter 2), green and purple fruits are predominant (47% and 38% of the total number of eggplant accessions, respectively). The main fruit shapes in this collection are slightly longer than broad (31.1% of accessions) and as long as broad (18.7% of accessions). There are also large variations in taste, fruit dry matter content, total sugars content, fiber content, and antioxidant activity, although studies on these characters are limited (AVRDC, 1996; Hanson et al., 2006).

Less information is generally available regarding resistance of genebank accessions to pests and diseases, or tolerance to abiotic stresses. Evaluations of accessions in genebanks are conducted from time to time, as resources permit. Thirty-eight of 200 eggplant accessions held at the World Vegetable Center (WorldVeg) showed some level of resistance to bacterial wilt (AVRDC, 1999). Other accessions have shown resistance to pests (Srinivasan, 2009). Genebank accessions of scarlet and gboma eggplants have shown resistance to two-spotted spider mite [*Tetranychus urticae* Koch (Acari: Tetranychidae)] (Taher et al., 2019).

Data from phenotypic studies can be difficult to interpret due to environmental effects on various traits. Hence, several descriptors and methods have been developed especially for eggplant by the International Union for the Protection of New Varieties of Plants (UPOV), Bioversity International and the European Cooperative Programme for Plant Genetic Resources (ECPGR). Recent high-throughput phenotyping tools developed for tomato could be applied to eggplant (Prohens et al., 2012; Hurtado et al., 2012).

1.4.3 Genetic diversity studies

Marker systems for eggplants have developed rapidly. Initial studies utilized restriction fragment length polymorphisms (RFLPs), random amplified polymorphic DNA (RAPD) and amplified fragment length polymorphisms (AFLPs). Subsequent to these, studies utilized simple sequence repeats (SSRs, microsatellites), single nucleotide polymorphisms (SNPs) and genotyping by sequencing (Salgon et al., 2018). SNPs are now used routinely for high-throughput genotyping. This technology is useful for studying genetic relationships among accessions and species using data in libraries and databases (Barchi et al., 2019; 2021). Genome assemblies for eggplant have also been reported (Hirakawa et al., 2014; Barchi et al., 2019; Wei et al., 2020).

The National Agriculture and Food Research Organization (NARO) holds a global collection of eggplant materials. A study using SNP markers grouped these materials into clusters of cultivars that corresponded to their geographic origin. One cluster contained accessions from Europe, The Americas and Africa. A second cluster contained accessions from East Asia. A third cluster contained accessions from Southeast Asia, and a fourth cluster contained accessions from South and Southeast Asia (Miyatake et al., 2019).

Establishing a clear relationship between genotypic groups and phenotypic characters has been difficult. Cericola et al. (2013) examined 238 eggplant accessions from Asia and the Mediterranean using microsatellite markers and phenotypic traits (19 fruit and plant characteristics) and were able to identify three groups based on the genotyping data. However, these three groups contained accessions both from Asia and from the Mediterranean, and the correlation between genotypic and phenotypic data was weak. A similar result was reported by Hurtado et al. (2012). However, using a more limited genepool, reasonable levels of correlation have also been reported (Prohens et al., 2005; Munoz-Falcon et al., 2009).

1.5 Major constraints to production

1.5.1 Diseases

Common diseases of eggplant include bacterial wilt, *Verticillium* wilt, *Fusarium* wilt and brinjal little leaf (Lebeau et al., 2011). Other diseases and pathogens that cause problems include *Alternaria* rot, *Anthrac-*

nose fruit rot, damping-off disease, *Phytophthora* blight, mosaic viruses and viroids (Rotino et al., 1997).

Bacterial wilt is caused by *Ralstonia solanacearum* (Smith) Yabuuchi. This bacterium has a range of other host plants including potato, tomato, and pepper (Yabuuchi et al., 1995). Roots are generally infected by bacteria in the soil, although the pathogen can also be spread via infected planting materials, tools, or irrigation water. The most severe infections occur under high temperatures and the typical symptom is wilting due to damaged roots and stems (Genin and Denny, 2012). Crop rotation combined with clean planting materials and hygiene measures are key methods to avoid bacterial wilt. Control by spraying is not possible. Grafting of eggplant scions onto resistant rootstocks can be effective (Huet, 2014; Keatinge et al., 2014). Some studies have focused on the identification of resistant genetic materials (AVRDC. 1999; Namisy et al., 2019). Eggplant CWRs are also of interest in efforts to develop resistant lines.

Fusarium wilt is caused by *Fusarium oxysporum* f. sp. *melongenae*. The fungus is soil-borne and has other host plants such as tomato and pepper. The first symptom is leaf discoloration, which later develops into wilting of foliage followed by root and stem damage. Raised beds can reduce the infection. Crop rotation can also reduce the problem because the fungus can survive from one year to the next on plant debris or as chlamydospores in the soil. Fungicides are not effective, therefore breeding resistant varieties is a likely strategy for control.

Verticillium wilt is caused by *Verticillium dahliae* Kleb. The fungus has many host plants and can survive for several years in the soil. Leaves first become curled and discolored, and later, the plants show senescence symptoms. Crop rotation can reduce the infection but at least two years without hosts is required for effective control. The soil can be fumigated or treated with fungicides before planting, but resistant varieties are a preferable alternative. Resistance genes have been identified in eggplant CWRs. The use of resistant tomato rootstocks is also an alternative.

Viruses, viroids and phytoplasmas

Eggplants are subject to attack by numerous viruses, viroids and phytoplasmas. Strategies to manage these pathogens are very important for the management of materials in genebanks and for germplasm exchange

Table 1.2. Some common viruses, viroids and phytoplasmas associated with eggplant (*Solanum melongena*) with current distribution and transmission vector (A = aphids, B = beetle, FB = flea beetle, L = leafhopper, M = mechanical, S -= seed, T = thrips, W = whitefly).

Pathogen	Genus	Vector	Distribution
Virus			
Alfalfa mosaic virus (AMV)	*Alfamovirus*	A,M,S	Global
Beet curly top virus (BCTV)	*Becurtovirus*	L	Global
Cucumber mosaic virus (CMV)	*Cucumovirus*	A,M,S	Global
Eggplant mosaic virus (EMV)[1]	*Comovirus*	FB,M	South America
Eggplant mottled crinkle virus (EMCV)	*Tombusvirus*	M	Middle East, Greece, India, Japan, Taiwan, Italy
Eggplant mottled dwarf virus (EMDV)	*Nucleorhabdovirus*	L,M	Mediterranean basin
Potato virus X (PVX)	*Potexvirus*	M, S	Global
Potato virus Y (PVY)	*Potyvirus*	A, M	Global
Tobacco mosaic virus (TMV)	*Tobamovirus*	M,S	Global
Tobacco ringspot virus (TRSV)	*Nepovirus*	FB	Global
Tomato brown rugose fruit virus (ToBRFV)	*Tobamovirus*	M,S	Europe, China, Middle East
Tomato leaf curl New Delhi virus (ToLCVND)	*Begomovirus*	W	SE and E Asia, Middle East, Indian Subcontinent
Tomato yellow leaf curl Kanchanaburi Virus (TYLCKaV)	*Begomovirus*	W	SE Asia[2]
Tomato spotted wilt virus (TSMV)	*Orthotospovirus*	T	Global
Viroid[2]			
Potato spindle tuber viroid (PSTVd)		M	Global
Eggplant latent viroid (ELVd)	*Elaviroid*	M,S	Spain[3]
Phytoplasma			
Little leaf disease		L	Asia, Africa, USA

[1] Synonymous with Andean potato mottle virus (APMoV).
[2] WorldVeg tests for PSTVd and the following viroids prior to seed distribution: pepper chat fruit viroid (PCFVd), tomato apical stunt viroid (TASVd), tomato chlorotic dwarf viroid (TCDVd), tomato planta macho viroid (TPMVd) and columnea latent viroid (CLVd).
[3] Pers. Comm, Yuan-li Chan, Virologist, WorldVeg.

(Table 1.2). Some of the listed pathogens currently have quarantine status (e.g., potato spindle tuber viroid), while others do not (e.g., eggplant mottled dwarf virus). Many viruses that infect eggplant are distributed globally, while others are currently restricted to specific geographic regions or countries. These pathogens can be transmitted by a variety of insect vectors, through contaminated seed or pollen, and mechanically as a result of handling or wounding plant materials with contaminated tools or equipment. Yield losses associated with viruses, viroids and phytoplasmas vary widely but sometimes approach 100% (Rao and Kumar, 2017; Rao and Reddy, 2020). The host range of these pathogens also varies widely, but often includes other important Solanaceous crop plants such as tomato and pepper. Viruses infecting other crops can also be transmissible to eggplant where they may remain visually undetected (Gramazio et al., 2019b). Brinjal little leaf is caused by a phytoplasma transmitted by leafhoppers and the first symptom is small leaves that turn yellow. Later, the whole plant is affected and fruit setting and yield are reduced (Rao et al., 2010). Not only tomato and pepper, but also Solanaceous weeds may serve as host plants for the phytoplasma. Therefore, controls must target the vector and other hosts. Little work has been done to screen or breed for resistance to this disease.

1.5.2 Pests

Common pests of eggplant include eggplant fruit and shoot borer (*Leucinodes orbonalis* Guenee), two-spotted spider mite, and sweet potato whitefly (*Bemisia tabaci* Gennadius). In addition, leafhopper (*Amrasca devastans* Distant), aphid (*Aphis gossypii* Glover), thrips, spotted beetle, leaf roller, stem borer, and blister beetle can cause problems (Rotino et al., 1997).

Eggplant fruit and shoot borer is the major pest of eggplant crops in the tropics. The larvae cause the most damage as they feed on both shoots and flowers. In addition, the larvae enter the fruits which makes them unsuitable for consumption. Farmers apply insecticides to control the pest, but this has resulted in pesticide-resistant insects. There are reports of tolerant local eggplant varieties in India (Parker et al., 1995; Shivalingaswamy and Satpathy 2007) but complete resistance has been difficult to achieve.

Two-spotted spider mite causes severe yield losses worldwide. The insects feed on leaves by sucking water and nutrients. The first symptoms are white or yellow spots on the leaves, followed by severe leaf discoloration (bronzing) and sometimes plant death. This pathogen is generally controlled by spraying. Resistant cultivars have not been found. Biological control is used in protected environments but not in open fields (Taher et al., 2019).

Sweet potato whitefly directly damages the leaves leading to reduced fruit size and fruit yields (Rakha et al., 2017; Taher et al., 2020). Indirect damage also occurs as whitefly transmits viruses. Whitefly is difficult to control as it has a high reproductive capacity and quickly develops resistance to pesticides (Rakha et al., 2017). Farmers control whitefly by spraying, but this is expensive and harmful to the environment. Biological measures have so far proven to be ineffective in open fields, and no resistant cultivars have been identified (Taher et al., 2020). The use of eggplant CWRs as a source of resistance remains to be determined.

1.5.3 Abiotic stress

Flooding, extreme heat and drought are major concerns in many eggplant-producing countries. Eggplants take several months to reach the mature (fruit-producing) stage, so they are more likely to encounter periods of unfavorable weather than are short-season crops. High soil salinity is another common problem.

1.6 Eggplant breeding

1.6.1 Breeding aims

Brinjal eggplant (*S. melongena*) breeders aim to develop cultivars with high yields and fruits that appeal to the market. Other aims are resistance to pests and diseases and adaptation to abiotic stresses. Important fruit quality traits include shape and color, but also nutritive value and the levels of sugars, anthocyanins and total phenols. To avoid the browning of cut fruits, low levels of polyphenol oxidase activity and phenolic compounds are desirable. Compared with many other global crops, eggplant has received less attention from breeders, mainly because its production is concentrated in developing countries where there is limited investment in breeding (Daunay and Hazra, 2012). Eggplant breeding programs in the private sector often aim to produce F_1 hybrids. Tolerance to high temperature, saline soils and drought are traits of interest. Breeding for biotic stress resistance focuses on resistance to wilt-causing pathogens including *R. solanacearum*, *F. oxysporum* f. sp. *melongenae* and *V. dahlia*, as well as resistance to nematodes and insect pests including eggplant fruit and shoot borer, sweet potato whitefly, two-spotted spider mite, leafhopper and aphid (Taher et al., 2017) – as noted previously.

Scarlet eggplant (*S. aethiopicum*) is increasingly becoming a high-input, market-oriented crop (Chadha and Mndiga, 2007). In response, WorldVeg has started a regional breeding program for scarlet eggplant in sub-Saharan Africa. This breeding program uses the germplasm collection of *S. aethiopicum* held at the WorldVeg genebank in Tanzania. By 2017, the internal rate of return on investment in the breeding program was 12.3%, and this is expected to increase to 26.0% by 2024 as lines are increasingly adopted by national institutions and seed companies in several African countries (Schreinemachers et al., 2017). Since 2018, this breeding program has connected with the seed enterprises of the Africa Vegetable Breeding Consortium (AVBC), which is coordinated by WorldVeg and the African Seed Trade Association. In 2019, seed companies from the AVBC rated African eggplant and leafy nightshade (*Solanum scabrum*), as their fifth and sixth priority crops, respectively, for breeding for markets in Africa, after onion, pepper, tomato and amaranth (Benali et al., 2020). These species are also popular components of seed kits for home and school garden development. More than 23,007 seed packs of leafy nightshade, 22,248 of scarlet eggplant, and 1840 of gbomba eggplant were distributed to farmers in Tanzania, Kenya and Uganda for home garden establishment between 2013 and 2017 (Stoilova et al., 2019).

Agronomic objectives for African eggplant breeding include early maturity and repeated fruit harvest (Dinssa et al., 2016) The major quality traits of interest, especially in Tanzania, are an elongated fruit shape, fruit with a creamy to green color, thin skin and few seeds. Taste preferences vary from sweet to medium-bitter to bitter. Other breeding objectives include resistance to wilt diseases (*F. oxysporum*, *Verticillium* spp.) and early blight (*A. solani*), as well as grey leaf spot (*Stemphylium* spp.) and Southern blight (*Sclerotiorum rolfsii*) (Dinssa et al., 2016). Breeders are also attempting to develop lines resistant to two-spotted spider mite and eggplant fruit and shoot borer. Sources of resistance to these two pests have been found in *Solanum aethiopicum* (N'Danikou et al., 2021; Seck, 2012). It would also be desirable to breed lines resistant to aphids (*Aphis* spp.), flea beetles (*Epitrex* spp.), and leaf miners (*Liriomyza* spp.) (Dinssa et al., 2016).

1.6.2 Pre-breeding

It is important to identify desirable genotypes for use in eggplant breeding programs (Taher et al., 2017; Taher et al., 2019). Thus, an important first step in the breeding pipeline is the identification of available and/or targeted genetic resources. Targeted genetic resources might be promising landraces, open-pollinated cultivars, CWR or hybrid varieties. Only a few breeding programs have tried to develop introgression lines from wild species (Rotino et al., 2014). Wild relatives grow in a range of environmental conditions and some are resistant or tolerant to important pests and diseases and/or abiotic stresses (Daunay and Hazra, 2012; Plazas et al., 2016; Syfert et al., 2016).

Some efforts have been made to introduce useful traits from CWR into *S. melongena* (Ano et al., 1991), and there has been some progress in generating lines with resistance to bacterial wilt and *Fusarium* wilt.

The eggplant pre-breeding work under the CWR Project is a good example of recent eggplant pre-breeding efforts. The main challenges in using CWR in a breeding program are linkage drag and various incompatibility barriers that exist between cultivated and wild species (Frary et al., 2007). Ideally, pre-breeding projects would be a shared responsibility. For example, they would include international collaborations and/or public-private partnerships with support from both breeding companies and the governments of the main eggplant-producing countries. Pre-breeding efforts could broaden the genetic base of cultivated eggplant and result in the development of new cultivars with significant levels of pest and/or disease resistance.

Pre-breeding objectives (using CWR) may include the following activities: A) Identification of desirable genetic resources among CWR by screening of genebank accessions; B) Development of mapping populations (by crossing the CWR with cultivated eggplant) and identification of the genes of interest in those populations; C) Production of pre-breeding materials by transferring traits of interest into elite materials; and D) Characterization of the pre-breeding materials to evaluate them for traits of commercial interest and resistance to biotic and abiotic stresses.

1.6.3 Traditional breeding and hybridization

Traditional breeding has been used to improve the agronomic traits of eggplant and produce F_1 hybrids. In the 1980s, more than 90% of the eggplant varieties produced by breeding companies were hybrids. Today this number is close to 100%. Breeders have worked to develop hybrid varieties with good yields and high fruit quality, earliness, and reduced prickliness and bitterness. Manual emasculation and pollination of inbred parents is time-consuming. The incorporation of cytoplasmic male sterility into breeding lines saves time and reduces costs. Hence, some male-sterile lines have been developed. This was achieved by crossing cultivated eggplant (as the male parent) with various wild species such as *S. violaceum*, *S. virginianum*, *S. grandifolium* and *S. anguivi*, followed by generations of backcrossing.

Cultivated eggplants are largely self-pollinated, but some outcrossing may take place *via* insects. Brinjal eggplant (*S. melongena*) is a day-neutral plant. A temperature range of 21°–27°C is ideal for fruit setting. Anthesis and pollen dehiscence occur in the morning, and both of these processes are strongly influenced by daylight, temperature and humidity. Emasculations and hybridizations are carried out in the morning before the temperature gets too high. Anthers are removed using forceps and then flowers are covered with small paper bags to avoid contamination.

Breeding methods for eggplants include pure line selection, pedigree selection, single seed descent, backcrossing, and heterosis and double-haploid methods. Mutation breeding has also been used to some extent. Biotechnological methods utilized include embryo culture, haploidization and somatic embryogenesis. A brief description of the different methods is given below.

Pure-line selection utilizes individual plants that are characterized, selected and harvested separately. This method is useful for heterogeneous materials, for example, diverse eggplant landraces or populations. In the first year, the original stock is planted. The desired plants are then selected and seeds are harvested from them. The next year, plant progenies (in rows) are planted and those with desirable traits are again selected. Seeds of plants within a selected progeny row are bulked and these new lines are considered for further trials.

The pedigree method uses individual plants that are selected from within a segregating population after a cross. The selection is conducted individually but is based on pedigree records. Selection of appropriate parental material is crucial for success. Breeders should select a parental line that is superior but lack a few desirable traits that the other parental line has.

The single seed descent method uses a selection procedure where F_2 plants and their progenies are advanced by utilizing only a single seed from each plant until genetic purity is attained (usually up to F_{6-7}). Thereafter, the pedigree method can be applied.

The back-crossing method is used to transfer traits controlled by a single dominant gene. This method can be used when CWR are used as gene sources. F_1 plants are back-crossed to the elite genotype (female parent) and selections of the resultant progeny are also repeatedly back-crossed.

Heterosis and doubled-haploid methods are used to develop F_1 hybrids of commercial interest (Collonnier et al., 2003; Frary et al., 2007). Doubled-haploid methods can be applied to eggplant to overcome the limitations of classical breeding techniques to generate pure lines for producing uniform F_1 hybrid seed. Here, anther and microspore cultures can be used to obtain doubled-haploid plants.

Mutation breeding involves the induction of mutations via gamma irradiation or chemical mutagens. Although this method was first developed in the 1930s, it has not been used extensively for eggplant breeding. Only a few varieties developed by mutation breeding have been officially released, as referenced in the Mutant Varieties Database. After mutagen treatments, breeders need to evaluate large plant populations to select plants with desirable traits. The frequency of plants with desirable traits is usually very low and they are most often recessive.

Hybridization of eggplant with its CWRs is a means to broaden the genetic base of eggplant by taking advantage of the genetic diversity of wild species. Embryo culture and somatic hybridization have been applied to overcome sexual incompatibility barriers between eggplant and some of its CWR (Collonnier et al., 2003). The development of introgression lines with *S. incanum* (Gramazio et al., 2017), for adaptation to climate change, has been reported. Backcross generations using *S. linnaeanum* and *S. tomentosum* for resistance to Fusarium wilt, Verticillium wilt, and nematodes, have also been reported. Germplasm evaluation to identify sources of tolerance to abiotic stresses such as drought, salinity or extreme temperatures, have been conducted. Some wild species are more tolerant of abiotic stresses than cultivated species. For example, García-Fortea et al. (2019) found that *S. elaeagnifolium*, a particularly drought-tolerant species, had a root system that occupied a larger volume than that of *S. melongena*.

Rootstock breeding is another strategy that may be useful for management of various biotic and abiotic stresses in eggplant. To manage bacterial wilt in eggplant crops, interspecific hybrid rootstocks have been developed from crosses between a cultivated eggplant resistant to bacterial wilt and an eggplant CWR (Rakha et al., 2020).

1.6.4 Marker-assisted breeding and genomics

In a marker-assisted breeding effort it is important to identify markers linked to particular traits of interest. Different marker systems have been applied for targeting major genes and quantitative trait loci (QTLs) in eggplant (e.g., Doganlar et al., 2002; Barchi et al., 2012; Daunay and Hazra, 2012; Cericola et al., 2014; Portis et al., 2014, 2015; Toppino et al., 2016). Early marker systems, such as those using RFLPs, RAPDs or AFLPs did not require genome sequence knowledge, but were nonetheless used successfully. The development of SSR and SNP markers required genome sequence information.

More than 200 QTLs associated with morphological and agronomic traits have been detected in eggplant. In some cases, QTLs for different traits, sometimes both desirable and undesirable (e.g. increased yield and prickliness) cluster together, revealing a likely pleiotropic effect of some QTLs (Portis et al., 2014). Similarly, several QTLs for anthocyanin content were found to cluster together (Barchi et al., 2012). Wei et al. (2020) identified 210 markers associated with 71 traits of interest in eggplant. Fine-mapping of a segregating eggplant population revealed a deletion in the eggplant genome associated with the occurrence of spines (Miyatake et al., 2020).

Like many other crops, eggplant has been the subject of efforts to develop markers linked with disease resistance. A linkage map based on SNP markers has been developed for bacterial wilt, and one major and two minor QTLs associated with resistance have been identified (Salgon et al., 2017). A resistance gene for *Fusarium* wilt, *Rfo-sa1*, has been introduced from scarlet eggplant into brinjal eggplant (Toppino et al., 2008). One major (Barchi et al., 2018; Miyatake et al., 2016) and two minor QTLs associated with *Fusarium* wilt resistance have been identified (Mutlu et al., 2008; Miyatake et al., 2016). Resistance to *Verticillium* wilt has been introduced from *S. linnaeanum* into brinjal eggplant (Liu et al., 2015) and three QTLs have been identified (Barchi et al., 2018). Markers have also been developed for parthenocarpy -– an important trait that allows fruit set without pollination (Daunay and Hazra, 2012), and for fruit composition traits including the concentrations of anthocyanin, glycoalkaloids, sugars and organic acids (Toppino et al., 2016).

The first genome map of *S. melongena* was published in 2014 (Hirakawa et al., 2014). The draft genome of scarlet eggplant has also been published (Song et al., 2019). Regarding resequencing projects, one study used seven brinjal eggplant varieties and one *S. incanum* accession as parents of a multiparent advanced generation intercross (MAGIC) population (Gramazio et al., 2019a) and more than 9 million SNPs were discovered in the eight parents (Barchi et al., 2021).

For scarlet eggplant, a resequencing project covering 65 accessions detected genes related to resistance and drought tolerance (Song et al., 2019).

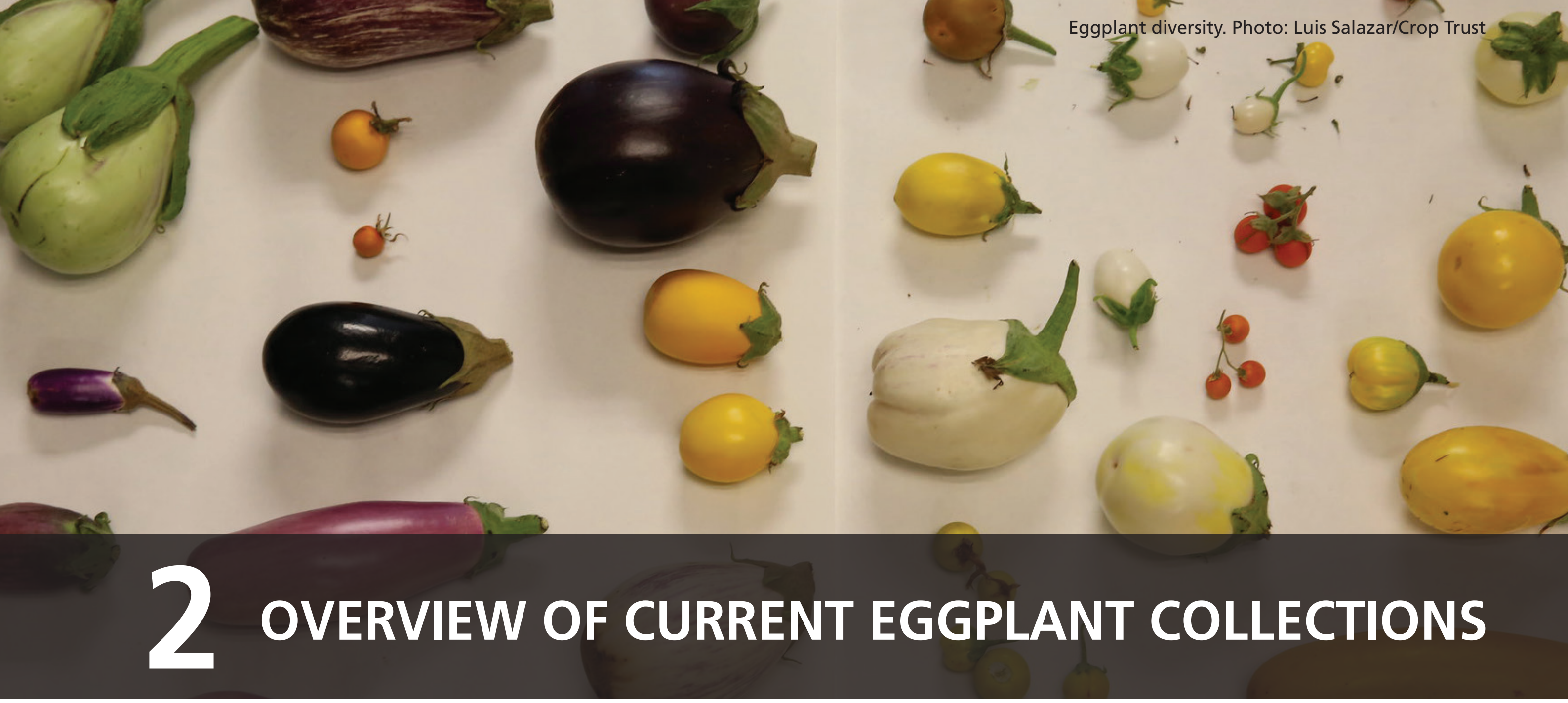
Transcriptomic and RNA-sequencing studies have also been performed for the eggplant genepool. Gramazio et al. (2016) developed many markers for scarlet eggplant. The transcriptomes of wild species (*S. aculeatissimum*, *S. sisymbriifolium*) have been mined for genes related to disease resistance, and that of *S. incanum* has been mined for genes related to drought tolerance (Yang et al., 2014; Gramazio et al., 2016; Zhou et al., 2016; Wixom et al., 2018). Few studies have analyzed the transcriptomes of cultivated *S. melongena* (Gramazio et al., 2018).

1.6.5 Genetically modified eggplants

Methods for gene modification in eggplant were developed in the late 1980s and several agronomic traits were successfully manipulated (Rotino et al., 2014). The most common type of genetically modified eggplant is transgenic *Bacillus thuringiensis* (Bt) plants (e.g., Acciarri et al., 2000). In south Asia, such transgenic varieties have been commercialized and show resistance to eggplant fruit and shoot borer and other pests (Shelton et al., 2018). Some researchers have produced transgenic plants with partial resistance to aphids (Ribeiro et al., 2006) and nematodes (Goggin et al., 2006; Papolu et al., 2016), or with resistance to wilt diseases caused by *Verticillium* (Xing and Chin, 2000; Singh et al., 2015), *A. solani* (Darwish et al., 2014) and *F. oxysporum* (Singh et al., 2014). Transgenic plants with increased tolerance to abiotic stresses have been developed in the laboratory (Kumar et al., 2014; Wan et al., 2014; Xiao et al., 2017) as have parthenocarpic plants (Donzella et al., 2000; Du et al., 2016). Transgenic methods have also been used to develop lines with reversible male sterility (Cao et al., 2010) and reduced fruit browning (Gianoglio et al., 2018).

1.7 Summary

In this chapter, we summarized and discussed information on the three cultivated eggplant species. The common eggplant *S. melongena* (brinjal eggplant or aubergine) is produced on 1.8 million ha of land, with 90% of its global production in Asia, especially in China and India. Two African eggplants, the scarlet eggplant (*S. aethiopicum*) and the gboma eggplant (*Solanum macrocarpon*), are often grown locally in Africa. Breeding and research efforts have focused on brinjal eggplant but are increasing for scarlet eggplant. Yield is an important breeding target for brinjal and scarlet eggplant, and most current breeding efforts aim to improve fruit yield and quality. However, resistance or tolerance to stresses are primary breeding objectives for stable performance under different environments. CWRs are seldom used in eggplant breeding (Rotino et al., 2014) and, to our knowledge, there are as yet no commercial varieties developed based on the use of CWR. The screening CWRs should be intensified and broadened. This is expected to result in the identification of germplasm accessions for breeding improved eggplant varieties. In this respect, studies should use molecular markers when appropriate and evaluate many traits simultaneously to identify materials with resistance to multiple biotic and abiotic stresses.



Eggplant diversity. Photo: Luis Salazar/Crop Trust

2 OVERVIEW OF CURRENT EGGPLANT COLLECTIONS

Genetic resources of cultivated eggplants are safeguarded in *ex situ* in genebanks around the world. Some genebanks and botanical gardens also maintain *ex situ* collections of CWR, but such genetic resources are often underrepresented in *ex situ* repositories (Castañeda-Álvarez et al., 2016).

2.1 *Ex situ* conservation reported to FAO and in Genesys

The data used in the following overview were retrieved in June 2021 from two global databases, Genesys and WIEWS, using the following procedure:

1) All accessions within the genus *Solanum* were downloaded from Genesys and WIEWS.

2) The two datasets were merged to create one dataset. If the same accession (same accession number and same genebank where it is conserved) were recorded in both WIEWS and Genesys, the accession was recorded in only one row of the dataset to avoid double counting. The same accession conserved in two different genebanks (duplicate holdings) were retained in separate rows in the dataset.

3) Taxa names were standardized across the dataset following the list in Appendix 5.

4) The dataset was filtered to retain only accessions in the eggplant genepool. This was achieved by retaining only the accessions with a standardized taxon name from the list in Appendix 4.

As a result, 110 collections containing eggplant materials in 76 countries were identified (Table 2.1). In total, the collections hold 15,910 eggplant accessions, including the three cultivated species and some CWR. Five collections contain 500 or more eggplant accessions. The largest collections are: 1) The National Bureau of Plant Genetic Resources (India, 4236 accessions); 2) WorldVeg (International organization, 3036 accessions); 3) The NARO Genebank (Japan, 1501 accessions); 4) The USDA collection in Griffin, Georgia (USA, 870 accessions); and 5) The Centre for Genetic Resources (the Netherlands, 516 accessions).

Most eggplant collections are small, with 78% holding fewer than 100 accessions and 54% holding fewer than 20 accessions.

2.2 Additional collections not included in Genesys and WIEWS

Of the 193 countries recognized by the United Nations, 123 have no eggplant collections listed in Genesys or WIEWS. Some of these countries are very small and would not be expected to have eggplant collections. Other countries, such as Nordic countries, are in climate zones where eggplants would not thrive and so they would also be unlikely to conserve eggplant materials. Of the remaining countries, approximately 60 do not have collections listed in the global databases but may contain other unlisted collections. Most of these countries are developing countries in Africa and Asia, but there are some exceptions, such as Australia, Republic of Korea, Uruguay and South Africa. Three of the major eggplant-producing countries, China, Iran and Indonesia, do not have collections listed in Genesys and WIEWS. In addition, the Russian eggplant collection at the N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR) is not listed in the databases. Therefore, additional literature searches were conducted, and attempts were made to contact potential collection holders in those countries to obtain more information.

Contacted institutions in China did not reply. However, the National Genebank for Vegetable Germplasm Resources in Beijing is reportedly the largest unit for vegetable seed conservation, and it holds 1601 eggplant accessions (Wang et al., 2018). In Indonesia, 200 eggplant accessions are conserved (ICABIOGRAD, 2018). Information on eggplant holding in Iran was not obtained. Information on eggplant holdings in Russia, Thailand and Myanmar was obtained via personal communications (see Chapter 3). All collections considered, the total eggplant holdings globally are 19,154 accessions. There are likely additional collections not included in this number. The Solanaceae collection of Radboud University (The Netherlands) ceased to exist in 2018. This collection, which held more than 3000 accessions of wild Solanaceae (including CWR of eggplant) was transferred to the Center for Genetic Resources, The Netherlands (CGN) for secure storage. Those materials are not included in the databases and the accessions are not currently available for distribution. The fate of this collection is an issue that should be addressed.

2.3 Relationship between production and conservation

Information on eggplant production and the number of conserved accessions was available for 43 countries. A correlation analysis (Figure 2.1) shows the relationship between the two variables. However, the result was strongly influenced by data from India (with approximately 727,000 ha of eggplant cultivation annually and 4236 conserved accessions), China (approximately 780,000 ha and 1601 accessions), and UK (no recognized eggplant cultivation and 393 accessions). Some countries, such as the Netherlands, have extensive collections but limited eggplant production.

Some collections are used to support global conservation efforts, breeding and research, rather than con-

Table 2.1. Eggplant collections listed in Genesys and WIEWS and their holdings. Institutes are sorted by FAO country and institution code. Additional collections identified through other sources are listed at the end of the table, alongside the information source.

FAO Code	Name of holding institute	Country	Number of accessions
ALB026	Plant Genetic Resources Center	Albania	12
ARE003	International Center for Biosaline Agriculture	International, United Arab Emirates	22
ARG1342	Banco Base de Germoplasma, Instituto de Recursos Biológicos, Instituto Nacional de Tecnología Agropecuaria	Argentina	2
ARG1350	Banco Activo de Germoplasma de La Consulta	Argentina	12
ARM008	Scientific Centre of Vegetable and Industrial Crops	Armenia	265
ARM059	Scientific Center of Agrobiotechnology	Armenia	5
ARM005	Institute of Botany, National Academy of Sciences of Armenia	Armenia	3
ARM035	Research Center for Plants Gene Pool and Breeding	Armenia	3
AUT025	Office of the Styrian Regional Government, Department for Plant Health and Special Crops	Austria	5
AZE005	Vegetable Growing Research Institute Public Legal Entity	Azerbaijan	30
AZE007	Viticulture and Wine-making Research Institute	Azerbaijan	1
AZE015	Genetic Resources Institute	Azerbaijan	33
BEL002	Gembloux Agro-biotech, Université de Liège, Département des Sciences Agronomiques, Phytotechnie Tropicale et Horticulture	Belgium	1
BGD003	Bangladesh Agricultural Research Institute	Bangladesh	348
BGD014	Bangladesh Forest Research Institute (BFRI)	Bangladesh	2
BGD028	Bangladesh Institute of Nuclear Agriculture (BINA)	Bangladesh	25
BGD206	Lal Teer Seed Limited	Bangladesh	348
BGD215	Advanced Seed Research & Biotech Centre	Bangladesh	26
BGR001	Institute for Plant Genetic Resources 'K. Malkov'	Bulgaria	178
BIH039	Institute of Genetic Resources, University of Banja Luka	Bosnia and Herzegovina	4
BLR011	Republican Unitary Enterprise 'Scientific Practical Centre of the National Academy of Sciences of Belarus for Arable Farming'	Belarus	5
BOL317	Instituto Nacional de Innovación Agropecuaria y Forestal	Bolivia	4
BRA003	Embrapa Recursos Genéticos e Biotecnologia	Brazil	375
BRA012	Embrapa Hortaliças	Brazil	411
CAN004	Plant Gene Resources of Canada, Saskatoon Research and Development Centre	Canada	31
CHE001	Agroscope Changins	Switzerland	1
COL017	Corporación Colombiana de Investigación Agropecuaria, AGROSAVIA	Colombia	62
CRI001	Centro Agronómico Tropical de Investigación y Enseñanza	Regional	4
CUB014	Instituto de Investigaciones Fundamentales en Agricultura Tropical	Cuba	8

FAO Code	Name of holding institute	Country	Number of accessions
CUB042	Instituto de Investigaciones Hortícolas Liliana Dimitrova	Cuba	3
CUB251	Instituto de Investigaciones Agropecuarias Jorge Dimitrov	Cuba	1
CYP004	National (CYPARI) Genebank, Agricultural Research Institute, Ministry of Agriculture, Rural Development and Environment	Cyprus	3
CZE122	Gene bank	Czechia	26
DEU146	Leibniz Institute of Plant Genetics and Crop Plant Research	Germany	134
ECU023	Departamento Nacional de Recursos Fitogenéticos	Ecuador	55
ECU167	Banco de Germoplasma de la Universidad Técnica Particular de Loja	Ecuador	1
EGY087	National Gene Bank	Egypt	26
ESP003	Comunidad de Madrid. Universidad Politécnica de Madrid. Escuela Técnica Superior de Ingeniería Agronómica, Alimentaria y de Biosistemas. Banco de Germoplasma César Gómez Campo	Spain	3
ESP026	Generalidad Valenciana. Universidad Politécnica de Valencia. Escuela Técnica Superior de Ingenieros Agrónomos. Banco de Germoplasma	Spain	223
ESP027	Gobierno de Aragón. Centro de Investigación y Tecnología Agroalimentaria. Banco de Germoplasma de Hortícolas	Spain	138
ESP200	Govern de les Illes Balears. Conselleria de Presidència. Direcció General d'Agricultura i Desenvolupament Rural. Institut de Recerca i Formació Agrària i Pesquera	Spain	7
ETH085	Ethiopian Biodiversity Institute	Ethiopia	67
FRA011	Unité de Génétique et Amélioration des Fruits et Légumes, Plant Biology and Breeding, INRAE Avignon	France	80
GBR004	Millennium Seed Bank Project, Seed Conservation Department, Royal Botanic Gardens, Kew, Wakehurst Place	United Kingdom	383
GBR006	Warwick Genetic Resources Unit	United Kingdom	8
GBR017	Henry Doubleday Research Association	United Kingdom	2
GEO001	Lomouri Institute of Farming	Georgia	2
GHA091	Plant Genetic Resources Research Institute	Ghana	22
GRC005	Greek Genebank, Institute of Plant Breeding and Genetic Resources	Greece	13
GUY021	National Agricultural Research and Extension Institute	Guyana	5
GTM001	Unknown	Guatemala	2
HUN003	Centre for Plant Diversity	Hungary	42
IND001	National Bureau of Plant Genetic Resources	India	4236
ISR002	Israel Gene Bank for Agricultural Crops, Agricultural Research Organisation	Israel	20
ITA363	Dipartimento di Chimica, Biologia e Biotecnologie, Universitá degli Studi Perugia	Italy	2
ITA391	CREA-Centro di Ricerca Orticoltura e Florovivaismo, Sede di Pontecagnano	Italy	2
ITA393	CREA-Centro di Ricerca Genomica e Bioinformatica, sede di Montanaso Lombardo	Italy	40
JOR105	National Agricultural Research Center	Jordan	32
JOR015	Agricultural Research Service	Jordan	32
JPN183	NARO Genebank	Japan	1501
KEN056	Genetic Resources Unit, ICRAF	International	15
KEN212	Genetic Resources Research Institute	Kenya	71
KGZ040	Bank-Laboratory of Plant Genetic Resources of the KR	Kyrgyzstan	8
LBN002	International Centre for Agricultural Research in Dry Areas	International	1
LBN020	Lebanese Agricultural Research Institute	Lebanon	1
LBY006	National Bank for Plant Genetic Resources	Libya	2
LKA036	Plant Genetic Resources Centre	Sri Lanka	208
MAR088	Centre Régional de la Recherche Agronomique de Settat	Morocco	5
MDA010	Laboratory for Plant Genetic Resources	Republic of Moldova	46
MEX367	Facultad de Ciencias Naturales, Universidad Autónoma de Querétaro	Mexico	4
MKD001	Faculty of Agriculture, University Ss. Cyril and Methodius	North Macedonia	4
MNG030	Institute of Plant and Agricultural Science	Mongolia	16
MWI041	Malawi Plant Genetic Resources Centre	Malawi	4

FAO Code	Name of holding institute	Country	Number of accessions
NGA010	National Centre for Genetic Resources and Biotechnology	Nigeria	110
NLD037	Centre for Genetic Resources, the Netherlands	Netherlands	516
NPL069	National Agriculture Genetic Resources Centre-Genebank	Nepal	11
PAK001	Bio-resources Conservation Institute	Pakistan	90
PHL008	Bureau of Plant Industry, Department of Agriculture	Philippines	6
PHL024	Bureau of Plant Industry-Davao National Crop Research and Development Center	Philippines	1
PHL129	Institute of Plant Breeding-National Plant Genetic Resources Laboratory	Philippines	34
PHL200	Department of Agriculture - Region 2	Philippines	2
POL003	Plant Breeding and Acclimatization Institute	Poland	18
PRT001	Banco Português de Germoplasma Vegetal	Portugal	1
ROM007	Suceava Genebank	Romania	43
ROM019	Research and Development Institute for Vegetables and Floriculture Vidra	Romania	134
ROM055	Research and Development Station for Vegetables – Bacau	Romania	32
SDN002	Agricultural Plant Genetic Resources Conservation and Research Centre	Sudan	75
SVK001	Plant Production Research Center Piestany	Slovakia	3
SWZ015	National Plant Genetic Resources Centre	Eswatini	1
THA300	Genebank	Thailand	6
TJK027	National Center for Genetic Resources	Tajikistan	11
TTO010	Central Experiment Station, Research Division, Ministry of Agriculture, Land and Fisheries	Trinidad and Tobago	1
TUN029	Banque Nationale de Gènes de Tunisie	Tunisia	1
TUR001	Plant Genetic Resources Department	Turkey	313
TUR034	Field Crop Central Research Institute	Turkey	20
TWN001	World Vegetable Center (WorldVeg)	Taiwan and Tanzania	3036
TZA016	National Plant Genetic Resources Centre	Tanzania	9
UGA132	Plant Genetic Resource Centre	Uganda	115
UGA130	Unknown	Uganda	8
UKR008	Ustymivka Experimental Station of Plant Production	Ukraine	6
UKR021	Institute of Vegetable and Melon Growing	Ukraine	371
USA016	Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station, USDA/ARS, Georgia.	USA	870
USA974	Seed Savers Exchange	USA	55
USA995	National Center for Genetic Resources Preservation	USA	1
UZB006	Uzbek Research Institute of Plant Industry	Uzbekistan	120
VNM049	Plant Resources Center	Vietnam	2
ZAF062	Genetic Resources Directorate, Department of Agriculture, Land Reform & Rural Development	South Africa	2
ZMB048	Zambia Agriculture Research Institute	Zambia	27
ZWE049	Genetic Resources and Biotechnology Institute, Ministry of Agriculture, Mechanization and Irrigation Development	Zimbabwe	3
N/A	National Genebank for Vegetable Germplasm Resources (source: Wang et al., 2018)	China	1601
N/A	Indonesian Center for Agricultural Biotechnology Research and Development (source: ICABIOGRAD, 2018)	Indonesia	200
N/A	Private breeder's collection, Kafrelsheikh University (source: Mohamed Rakha, personal communication)	Egypt	139
N/A	Department of Agricultural Research (DAR) (source: Htwe Min Thant, personal communication)	Myanmar	48
N/A	DOA Genebank (source: Kunyaporn Pipithsangchan, personal communication)	Thailand	426
RUS001	N.I. Vavilov All-Russian Institute of Plant Genetic Resources (source: Irina Gashkova, personal communication)	Russia	830
Total			**19,020**

tributing directly to national food production. Some countries, for example, Sudan, Egypt and Mexico, have significant levels of eggplant production, but conserve relatively few accessions (Figure 2.2). More effort is required to conserve eggplant resources in these countries, because there is a high risk of replacement with other crops.

2.4 Conservation by biological status

The overview in Table 2.2 covers accessions listed in Genesys and WIEWS but not those held in Chinese collections or other collections that are not listed in international databases.

Large proportions of the collections of brinjal eggplant (77.8%), scarlet eggplant (70.8%) and gboma eggplant (69.2%) have an unknown biological status. Biological status indicates if an accession is a cultivar, a landrace, a breeding line or wild. The category "other" is common and indicates that the biological status of the material is unknown, cannot be determined, or that this information has not been shared with the international community. As described in Chapter 3, it can be difficult to assign accessions a status of landrace or cultivar. Most of the accessions with unspecified biological status are likely to be local or heirloom cultivars. It would be an advantage to know the biological status of these materials, as such materials would have priority for conservation

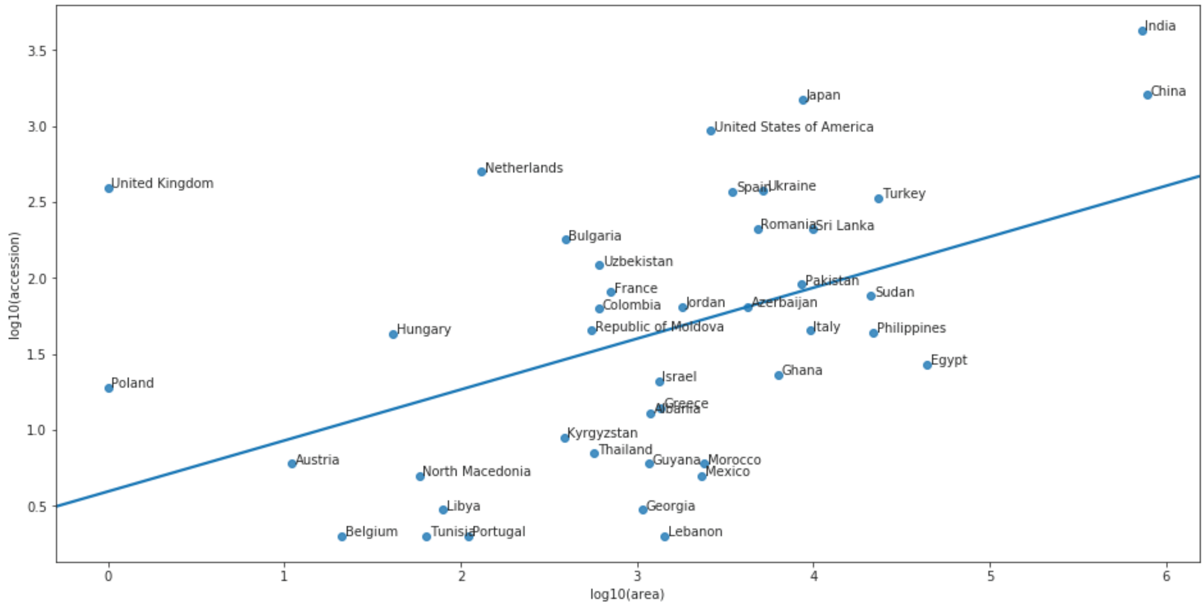


Figure 2.1. Number of conserved eggplant accession in selected countries (y-axis) versus production area of eggplant in the same countries (x-axis). Values were log10-transformed for clearer separation of countries on the graph. $R^2 = 0.22$.

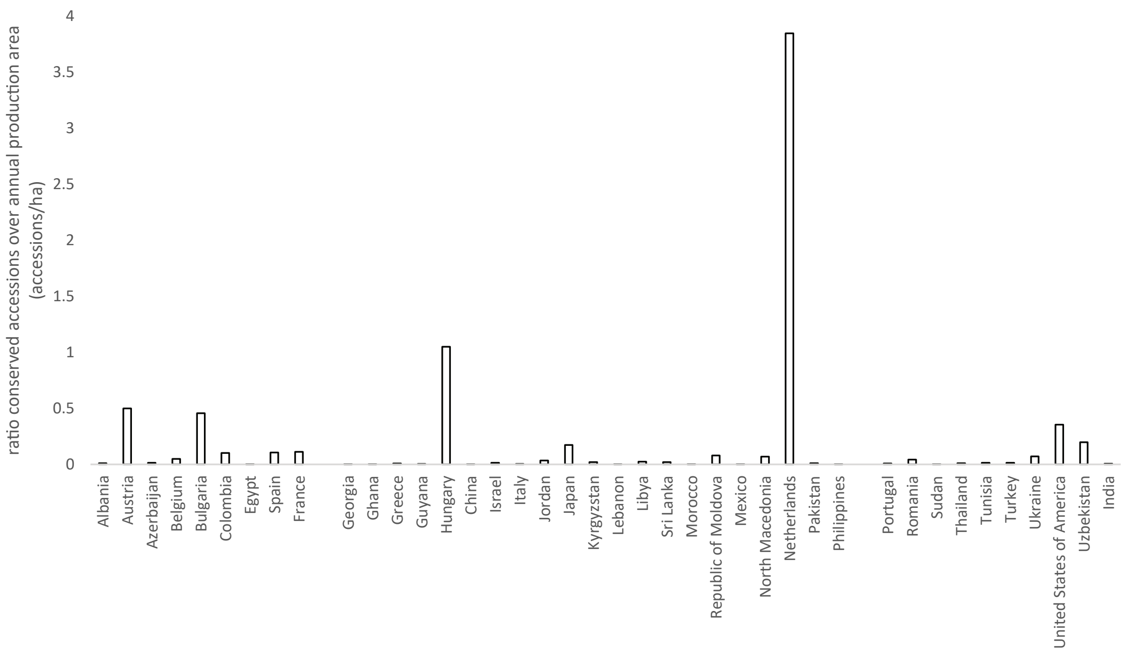


Figure 2.2. Ratio of number of conserved accessions to production area (in ha). Only countries for which this information was available are shown (United Kingdom and Poland were excluded as the production area according to FAO STAT was zero or not specified).

over modern varieties. Such materials are important components of crop evolution, as they are often derived from landraces and possibly have hybridized with CWR. For brinjal eggplant, there are very few accessions identified as wild material (see Table 2.2) in genebanks. For scarlet eggplant, around 8% of the accessions are defined as wild, while 2–3% are cultivars or breeding lines, indicative of some breeding activity for this plant. For gboma eggplant, there are no cultivars or breeding materials, which reflects the lack of breeding activity for this minor African crop.

2.5 Core collections

Core collections are created to facilitate distribution and evaluation (Brown, 1989). Subsampling strategies include selecting a fixed number of accessions in, or a proportion (%) of, the accessions that contain a large proportion of the genetic diversity present in the entire (base) collection. Both morphological and genetic analyses can be used to select core collections. For brinjal eggplant, core collections have been established at ICAR-National Bureau of Plant Genetic Resources in India (Gangopadhyay et al., 2010) and at NARO in Japan (Miyatake et al., 2019).

2.6 Conservation of crop wild relatives

2.6.1 *Ex situ* conservation of CWR

This section provides an overview of the *ex situ* conservation status of the CRWs of brinjal eggplant. The Harlan and de Wet CWR Inventory (Vincent et al., 2013) was used to identify target species. *Solanum bahamense* L. was omitted because it is neither an accepted taxon nor a synonym. One taxon, *S. cumingii,* was added. This species is native to Eastern Asia, but no *ex situ* accessions are listed in the global databases that were consulted.

The members of GP2 and GP3 varied between the Harlan and de Wet Inventory and other sources. The list presented here is according to the Harlan and de Wet Inventory. Vincent et al. (2013) found that among the 18 priority CWR taxa for eggplant, 78% had fewer than 50 accessions conserved *ex situ* (Appendix 4), and a similar level of *ex situ* conservation (77%) was identified in this analyses. Müller et al. (2021) pointed out that only a few populations of taxa from eggplant GP1 have been collected to date, and that more should be targeted. Indeed, according to our

Table 2.2. Overview of number of conserved accessions under each biological status category for the three cultivated eggplant species (data from Genesys and WIEWS, 2021).

Species	Biological status	Number of accessions	% of total
S. melongena **(brinjal eggplant)**			
	Wild species	13	0.1
	Landraces	1300	10.3
	Breeding materials	272	2.1
	Cultivars	484	3.8
	Others	757	6.0
	No info (unknown)	9839	77.8
	Total brinjal eggplant	12665	100
S. aethiopicum **(scarlet eggplant)**			
	Wild species	81	8.1
	Landraces	119	11.9
	Breeding materials	3	0.3
	Cultivars	23	2.3
	Others	67	6.7
	No info (unknown)	711	70.8
	Total scarlet eggplant	1004	100
S. macrocarpon **(gboma eggplant)**			
	Wild species	20	9.6
	Landraces	41	19.7
	Breeding materials	0	0
	Cultivars	0	0
	Others	3	1.4
	No info (unknown)	144	69.2
	Total Gboma eggplant	208	100

[A] Brinjal eggplant includes three accessions under the synonym *Solanum ovigerum*. Scarlet eggplant includes 87 accessions under the synonym *Solanum gilo* and 31 accessions under the synonym *Solanum integrifolium*.

Table 2.3. Number of conserved accessions (based on data from Genesys and WIEWS, and from the survey —see Chapter 3) for crop wild relatives of brinjal eggplant. Table contents are sorted by different genepools following the Harlan and de Wet CWR Inventory, but with two additional taxa from the CWR Priority Checklist (Vincent et al., 2013). Bold font highlights 18 taxa in the CWR Priority Checklist. IUCN categories are Red List categories, where LC=least concern, VU=vulnerable, and CR=critically endangered (see In situ Conservation section for details). Confirmed useful traits are listed, if known.

Crop Wild Relative taxon	IUCN category	Number of accessions: Genesys/ WIEWS	Number of accessions: Survey	Geographical distribution	Confirmed traits and references, or other comments
Primary genepool (GP1)					
***S. insanum* L. [A]**	-	**79**		E & S Asia	Bacterial wilt tolerance (Namisy et al., 2019, Rakha et al., 2020)
Sum: primary genepool		**79**			
Secondary genepool (GP2)					
S. adoense Hochst. ex A. Braun [B]	LC	3		E Africa	Synonym of S. anguivi Lam.
S. agnewiorum Voronts.	-	1		E Africa	
S. aldabrense C.H. Wright [B]	-	1		E Africa	Synonym of S. anguivi Lam.
S. aureitomentosum Bitter	LC	0		E & C Africa	
***S. campylacanthum* Hochst. Ex. A. Rich.[C]**	**LC**	**59**		E & S Africa	Whitefly resistance (Taher et al., 2020)
S. cerasiferum Dunal	LC	60		Africa	
S. deflexicarpum C.Y. Wu & S.C. Huang	-	0		China	
S. glabratum Dunal	LC	0		E Africa	
S. hovei Dunal	-	0		India	
***S. incanum* L.**	**LC**	**423**		C & W Asia, E & N Africa	Drought tolerance (Knapp et al., 2013), Verticillium wilt tolerance (Frary et al., 2007)
S. *lichtensteinii* Willd.	LC	2		S Africa	Drought tolerance (Plazas et al., 2016)
***S. linnaeanum* Hepper & P.M. L. Jaeger**	**LC**	**21**		E & S Africa	Salinity and fungal wilt tolerance (Liu et al., 2015).
S. litoraneum A.E. Gon	-	0		S Africa	
S. malindiense Voronts.	-	1		E Africa	
S. rigidum Lam.	VU	0		W Africa	
S. sodomeodes Kuntze	-	1		S Africa	
S. taitense Vatke	-	0		E Africa	
S. torreanum A.E. Gon	-	1		S Africa	
S. umtuma Voronts. & S. Knapp	-	0		S Africa	
S. usambarense Bitter & Dammer	-	1		E Africa	
S. vicinum A.R. Bean	-	1		Australia	
Sum secondary genepool		**575**			
Tertiary genepool					
***S. aculeatissimum* Jacq.**	**-**	**210**		Africa	Frost tolerance (Rotino et al., 2014)
***S. anguivi* Lam. [D]**	**LC**	**232**		Africa	
***S. anomalum* Thonn.**	**LC**	**57**		W & C Africa	
***S. asperolanatum* Ruiz & Pav. [E]**	**LC**	**41**		S America	
S. burchellii Dunal	LC	0		S Africa	
S. capense L.	LC	5		S Africa	
S. catombelense Peyr.	LC	5		E & S Africa	
S. cinereum R. Br.	-	4		Australia	
S. coagulans Forssk. [F]	LC	27		E & N Africa, W Asia	
***S. cumingii* Dunal. [B]**	**-**	**0**		E Asia	Synonym of S. undatum Lam.
S. cyaneopurpureum De Wild.	-	4		E & C Africa	
S. dasyphyllum Schumach.	LC	61		Africa	Whitefly resistance (Plazas et al., 2016, Taher et al., 2020)

Crop Wild Relative taxon	IUCN category	Number of accessions: Genesys/ WIEWS	Number of acces-sions: Survey	Geographical distribution	Confirmed traits and refer-ences, or other comments
S. forskalii Dunal	LC	0		Africa	
S. goetzei Dammer	LC	2		E & S Africa	
***S. grandiflorum* Ruiz & Pav.** [G]	**-**	**184**		S America	
S. hastifolium Hochst. ex Dunal	LC	11		E Africa	
S. humile Lam. [H]	LC	6		S Africa	
S. inaequiradians Werderm.	-	0		E Africa	
S. lamprocarpum Bitter	LC	0		E Africa	
***S. lidii* Sunding**	**CR**	**2**		S Europe	
S. macracanthum A. Rich.	LC	4		E Africa	
***S. macrocarpon* L.**	**-**	**208**		Africa	Good rootstock traits (USDA 2011), spider mite resistance (Taher et al., 2019)
S. marginatum L. f.	LC	21		E Africa	
S. mauense Bitter	LC	7		E Africa	
S. melanospermum F. Muell.	-	0		Australia	
S. nigriviolaceum Bitter	LC	3		S Europe, E Africa	
S. platacanthum Dunal	-	0		Yemen	
S. polhillii Voronts.	-	0		E Africa	
S. richardii Dunal	LC	2		E Africa	
***S. rubetorum* Dunal**	**LC**	**2**		S Africa	
S. ruvu Voronts.	-	0		E Africa	
S. setaceum Dammer	-	4		E Africa	
***S. sisymbriifolium* Lam.**	**-**	**60**		S America	Spider mite resistance (Taher et al., 2020)
S. stipitatostellatum Dammer	-	0		E Africa	
S. supinum Dunal	-	2		S Africa	
***S. tomentosum* L.**	**-**	**3**		S Africa	Whitefly resistance (Taher et al., 2020)
***S. torvum* Sw.** [I]	**-**	**358**		S & C America	Good rootstock traits (Daunay 2008), bacterial and fungal wilt resistance (Collonnier et al., 2003), root knot nematode resistance (Rotino et al., 2014), spider mite resistance (Taher et al., 2020)
S. usaramense Dammer	-	0		E Africa	
S. vespertilio Aiton	-	3		S Europe	
S. viarum Dunal	LC	97		S America	Eggplant fruit borer tolerance (Rotino et al., 2014)
***S. violaceum* Ortega** [J]	**-**	**93**		E & SE Asia	
S. virginianum L. [K]	-	187		E & SE Asia	
S. zanzibarense Vatke	-	0		E Africa	
Sum: tertiary genepool		**1905**			

[A] Includes three accessions under the synonym *S. ovigerum* and 53 accessions under the synonym *S. melongena* var. *insanum*.
[B] Defined as a species in the CWR Inventory but not accepted in GBIF.
[C] Defined as a species in the CWR Inventory but as a synonym in GBIF. Includes four accessions of the synonym *S. panduriforme*.
[D] Includes 71 accessions classified as *S. indicum*.
[E] Includes one accession classified as *S. hispidum*.
[F] Includes nine accessions classified as *S. dubium*.
[G] Includes 51 accessions classified as *S. acanthodes*.
[H] Includes two accessions classified as *S. rigescentoides*.
[I] Includes two accessions classified as *S. chrysotrichum*.
[J] Includes four accessions classified as *S. kurzii* and one accession classified as *S. violaceum*.
[K] Includes 53 accessions classified as *S. xanthocarpum* and 71 accessions classified as *S. surattense*.

data, several of the CWR are not conserved at all. Of the 18 priority taxa, five species have fewer than 50 accessions conserved (Table 2.3). The number of accessions could change slightly if the former Solanaceae collection of Radboud University is made available. Table 2.3 also lists abiotic and biotic stress tolerance or resistance traits in CWR, if known. Many of the CWR species have not yet been evaluated. Therefore, a blank cell does not necessarily mean that it has no desirable traits.

2.6.2 *In situ* conservation and red-listed CWR

Natural ecosystems and farmers have maintained plant genetic resources *in situ* or on farms for centuries and under shifting climatic conditions and management practices (Maxted et al., 2000; Nambi and Gopinath, 2020). The diversity of wild plants can be preserved *ex situ* only to a limited extent. In *ex situ* collections, evolution and adaptation are restricted by regeneration and cross-pollination processes and available technical expertise and resources. Therefore, *in situ* conservation of CWR is often suggested as being preferable to *ex situ* (e.g., Thormann 2020). However, although CWR may be present in protected areas, they are seldom monitored or actively managed. In practice, there are few examples of active *in situ* CWR conservation (FAO 2010), though guidelines on how to establish, manage and monitor CWR in such reserves are available in the literature (Gadgil et al., 1996; Stolton et al., 2006; Iriondo et al., 2008).

To our knowledge, there are no reports of active *in situ* conservation of eggplant CWR. In some countries,

Table 2.4. Number of landrace accessions sorted against the geographical groups in the eggplant diversity tree.

Group in the eggplant diversity tree	Estimate # of accessions counting only accessions recorded as landraces	Estimate assuming accessions with unknown biological status are landraces
Solanum melongena L. (accessions not falling in groups below)	11,414	2644
East Asia		
S. melongena China	45	228
S. melongena Japan	3	363
S. melongena Taiwan	5	72
S. melongena other East Asia	3	10
South Asia		
S. melongena India	46	3794
S. melongena Bangladesh	36	1034
S. melongena other South Asia	48	368
South East Asia		
S. melongena Philippines	140	308
S. melongena Thailand	195	524
S. melongena others Southeast Asia	97	577
Central and West Asia		
S. melongena Central and West Asia	159	1248
Europe		
S. melongena Mediterranean Europe	356	477
S. melongena others Europe	87	448
Africa		
S. melongena North Africa	27	65
S. melongena West and Central Africa	14	40
S. melongena East and Southeast Africa	5	36
S. melongena West Indian Ocean	4	6
S. melongena others Africa	1	2
Oceania		
S. melongena Oceania	0	7
Americas		
S. melongena America (excl. Caribbean)	18	411
S. melongena Caribbean (Including Belize, Guyana, Suriname and French Guiana)	15	35
S. melongena Others	3	10
Total *S. melongena* (excluding wild *S. melongena*)	12,705	12,705

national action plans have been developed for CWR that provide local approaches for *in situ* and *ex situ* conservation (Maxted et al., 2015; CGRFA 2017). A recent example is a list of CWR and their conservation status in Italy (Perrino & Wagensommer 2021), although this list did not contain CWR of eggplant. Eggplant CWR are present in the Mediterranean. African and Asian countries harbor many of the eggplant CWR, but few details are available on their *in situ* conservation.

For this report, the International Union for Conservation of Nature's Red List of Threatened Species for eggplant CWR was consulted. Among all the species identified as eggplant CWR in Table 2.3, two were on the Red List: *S. rigidum*, classified as vulnerable (Catarino et al., 2017) and *S. lidii*, classified as critically endangered (Rodríguez Delgado et al., 2011).

2.7 Conservation of landraces

To estimate the coverage of landraces against the group in the eggplant diversity tree passport data from Genesys and WIEWS was merged into a single dataset and accessions mapped to each group in the diversity tree. As a large proportion of eggplant accessions in Genesys and WIEWS are recorded with an unknown biological status, the analysis was conducted twice: first by counting only accessions recorded as landraces, second by counting all accessions recorded as landraces and with unknown biological status (i.e. assuming that most of the accessions with unknown biological status are landraces).

The results of this analysis (Table 2.4) suggest that landraces from Africa are a gap in *ex situ* collections (or at least a gap in the collections that share data

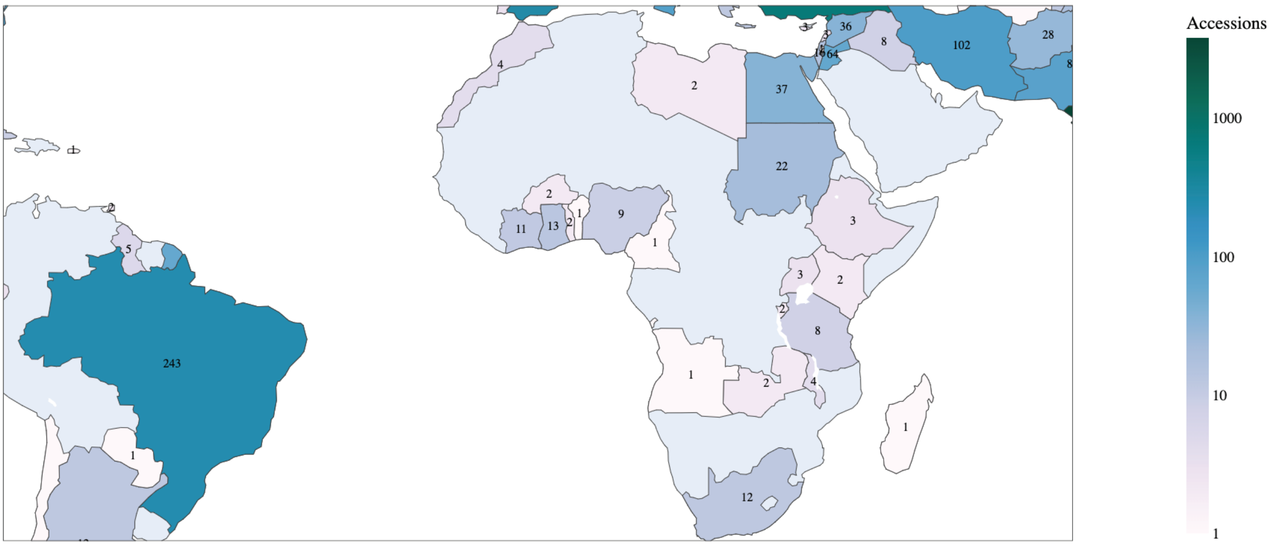


Figure 2.3. Choropleth map of Africa showing number of *S. melongena* accessions recorded as landraces or with unknown biological status by country of origin based on the data recorded in Genesys and WIEWS.

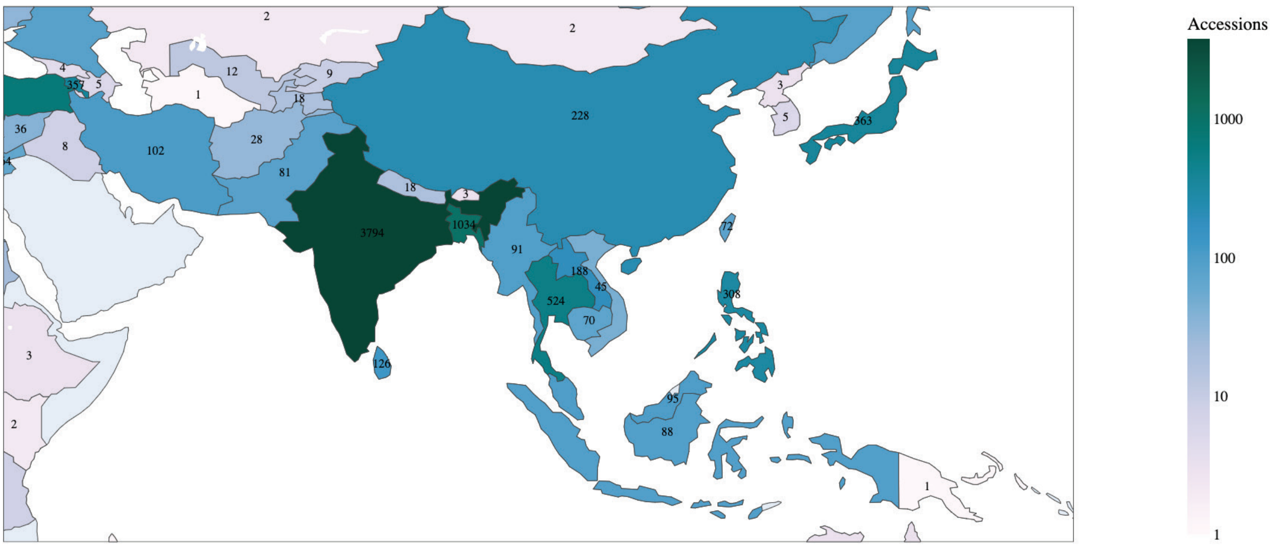


Figure 2.4. Choropleth map of South Asia, Southeast Asia and East Asia showing number of *S. melongena* accessions recorded as landraces or with unknown biological status by country of origin based on the data recorded in Genesys and WIEWS.

in Genesys and WIEWS). Madagascar is of particular interest for further collecting because this country has been an historic center of diversification with crop introductions from Southeast Asia and the African mainland (Pierron et al., 2017). Accessions by country of origin are also shown in Figure 2.3 and 2.4.

In Asia, Southeast Asia is not well represented *ex situ*. For example, aside from the Philippines and Thailand, Indonesia and Malaysia are considered important areas of diversity of *S. melongena* because of the size of these countries and the many islands in the Malay archipelago where varieties may have evolved separately. There are 88 and 95 accessions, respectively, from each of these countries.

In East Asia, excluding the accessions in China and Japan, 72 accessions from Taiwan were identified. This is a large number of accessions considering the small area of the island, and a potentially diverse set of germplasm considering the island's ecogeographic variation. A diversity analysis of the germplasm from the different geographic regions in East Asia will help to better understand the diversity in this region.

In South Asia, India has a large number of eggplant accessions. Considering the high level of diversity of eggplant found here, additional details on geographical coverage is desirable. However, the lack of coordinate data for the accessions reported in Genesys and WIEWS does not allow for this analysis to be meaningful. The result of a search on NBPGR portal suggests that the different states of India are well represented in the NBPGR collection. Bangladesh is a center of eggplant domestication (Larson et al., 2014) and is another important country of eggplant diversity. This is reflected in the high number of accessions reported.

In the Americas, the Caribbean, Guyanas and Belize form an interesting cluster of diversity because of possible multiple introductions by slaves, laborers, and others from Africa and Asia during colonial times. However, with only 9 accessions from Cuba, 1 from Puerto Rico and 2 from Trinidad and Tobago, eggplant from the Caribbean is not well represented in *ex situ* collections.

Finally, considering the incompleteness of passport data and that some important collections do not publish their accession data on Genesys and WIEWS, it is possible that the gaps mentioned above may be information gaps rather than collection gaps.

An assessment of the geographic coverage, at a national level, was also conducted for *S. aethiopicum*. It was found that accessions of this crop are mostly from West Africa and Brasil (Figure 2.5) as expected based on the areas where this crop is more important. Additionally, this crop is also cultivated in the Caribbean (no accessions found) and in Italy (2 accessions) (Plazas et al., 2014), but these regions are not represented *ex situ*.

2.8 Summary

This chapter provides an overview of eggplant germplasm collections around the world utilizing information from the global databases Genesys and WIEWS. The most frequently represented species is *S. melongena* (brinjal eggplant) with more than 12,000 accessions. This is followed by scarlet eggplant (*S. aethiopicum*) with 886 accessions and gboma eggplant (*S. macrocarpon*) with 209 accessions. Data for eggplant CWR are also provided. Some priority species have very few conserved accessions, while other species are well represented.

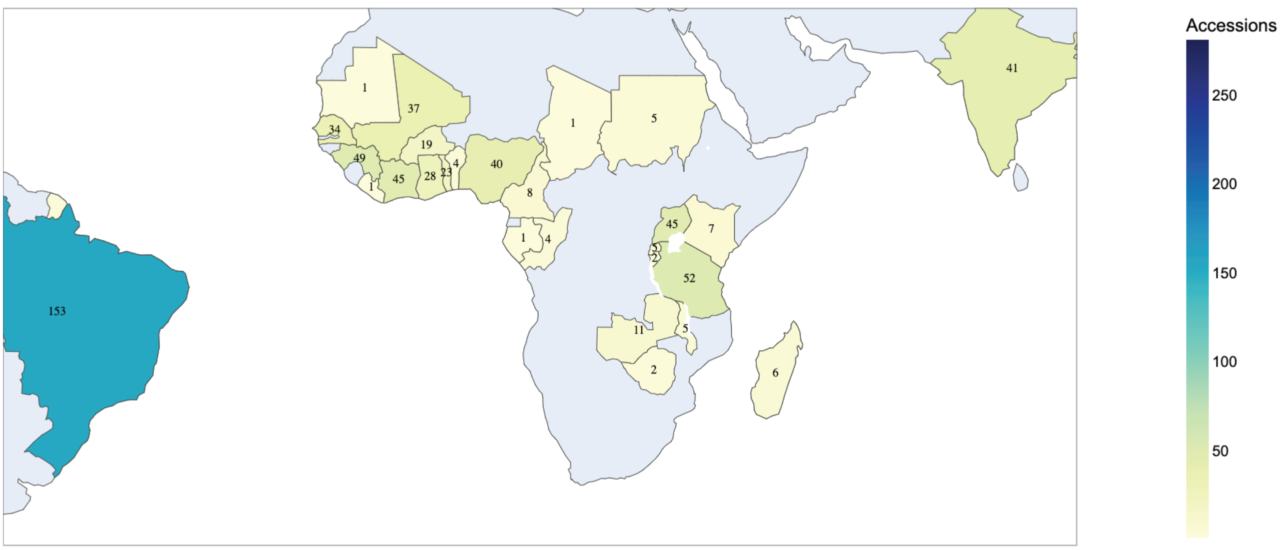


Figure 2.5 Choropleth map showing number of *S. aethiopicum* accessions recorded as landraces or with unknown biological status by country of origin based on the data recorded in Genesys and WIEWS.

3 SURVEY OF EXISTING EGGPLANT COLLECTIONS

3.1 General information on the collections

Surveys were sent to 90 collection holders for which contact details were available. Thirty-two responses were received, 28 of which had sufficient information to be included in the accession overview (Table 3.1). Twenty respondents were from national genebanks under the control of governmental organizations and five were from collections held at publicly-funded universities. Several were from genebanks at national research institutes, from international centers, or from non-governmental organizations.

In total, 17,190 accessions of eggplants and related CWR were reported by the 28 collection holders. This is slightly more than the number reported in Genesys and WIEWS (Chapter 2). Responses were obtained

Table 3.1. Overview of the survey respondents (below)

Institution	Location	Respondent name	Type of institution
Banque Nationale de Gènes	Tunisia	Najla Mezghani	Government
Institute of Vegetable and Melon Growing of NAAS	Ukraine	Roman Krutko	Research Institute
World Vegetable Center (WorldVeg)	Taiwan and Tanzania	Maarten van Zonneveld	International Agricultural Research Centre
ICAR-National Bureau of Plant Genetic Resources	India	Chithra Devi Pandey	Government
UK Vegetable Genebank	UK	Charlotte Allender	Publicly funded university
Federal Research Center the N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR)	Russia	Irina Gashkova	Government
The National Institute of Horticultural Research	Poland	Mariusz Chojnowski	Government
Scientific Center Vegetables & Industrial Crops	Armenia	Karine Sarikyan	Government
Agroscope	Switzerland	Beate Schierscher	Government
Embrapa Recursos Geneticos e Biotecnologia	Brazil	Juliano Gomes Padua	Government
Crop Research Institute	Czech Republic	Helena Stavělíková	Government
CSIR-Plant Genetic Resources Research Institute	Ghana	Yaw Kwateng	Government
Institute of Biosciences and BioResources (National Research Council)	Italy	Gaetano Laghetti	Government
Department of Agricultural Research (DAR)	Myanmar	Htwe Min Thant	Government
DOA Genebank	Thailand	Kunyaporn Pipithsangchan	Government
INRAE Centre for Vegetable Germplasm	France	Rebecca Stevens	Government
Faculty of Agricultural Sciences and Food, Skopje	North Macedonia	Sonja Ivanovska	Publicly funded university
The National Agricultural Research Center	Jordan	Khaled Abulaila	Government
Leibniz Institute of Plant Genetics and Crop Plant Research (IPK)	Germany	Ulrike Lohwasser	Government
National Plant Genetic Resources Centre	Zambia	Masiye Tembo	Government
Universitat Politecnica de Valencia	Spain	Maria Jose Diez	Publicly funded university
Agrifood Research and Technology Centre of Aragón (CITA – Aragón)	Spain	Cristina Mallor	Government
Seed Savers Exchange	United States	Philip Kauth	NGO
Centre for Genetic Resources, The Netherlands (CGN)	The Netherlands	W van Dooijeweert	Government
Plant Gene Resources of Canada	Canada	Dallas Kessler	Government
USDA/ARS	United States	Robert L. Jarret	Government
Private breeder's collection	Egypt	Mohamed Rakha	Privately funded
IPGR-Sadovo	Bulgaria	Gergana Desheva	Publicly funded university

from many of the larger genebanks, including the ICAR National Bureau of Plant Genetic Resources in India and WorldVeg in Taiwan and Tanzania. The responses revealed that the INRAE Centre for Vegetable Germplasm in France (FRA011) has a significant collection, but also many accessions not yet listed in the global databases, and that several other collections also have more accessions than are listed in Genesys and WIEWS.

Table 3.2 summarizes the number of accessions of different species and in different categories, as reported by the respondents. Most figures are similar to what is reported in Genesys or WIEWS. However,

Table 3.2. Overview of the respondents' eggplant collections based on the survey results. Number of accessions for brinjal eggplant and the two African eggplants are given by cultivars (including old (heirloom) cultivars) (CV), local cultivars or landraces (L), breeding lines (B), wild origin (W), from the primary genepool (W-P) or secondary/tertiary genepool (W-S/T).

	Brinjal eggplant					Scarlet and gboma eggplants				Total
Institution	**CV**	**L**	**B**	**W-P**	**W-S/T**	**CV**	**L**	**B**	**W**	**All**
Banque Nationale de Gènes, Tunisia	-	1	-	-	-	-	-	-	-	1
Institute of Vegetable and Melon Growing of NAAS, Ukraine	197	38	70	0	2	1	0	0	5	313
World Vegetable Center (International) A	2739	-	-	11	1046	569	-	-	-	4365
ICAR-National Bureau of Plant Genetic Resources, India	2019	1232	467	62	1082	13	15	1	3	4894
UK Vegetable Genebank	4	3	-	-	-	-	-	-	-	7
Federal Research Center the N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR), Russia	375	393	62	-	-	-	5	-	2	830
The National Institute of Horticultural Research, Poland	5	10	3	-	-	-	-	-	-	18
Scientific Center Vegetables & Industrial Crops, Armenia	-	-	-	-	-	-	-	-	-	194
Agroscope, Switzerland	-	10	-	-	-	-	-	-	-	10
Embrapa Recursos Geneticos e Biotecnologia, Brazil	-	-	-	-	4	-	72	-	-	378
Crop Research Institute, Czech Republic	21	-	-	-	-	-	-	-	-	21
CSIR-Plant Genetic Resources Research Institute, Ghana	30	30	30	-	12	36	23	23	1	649
Institute of Biosciences and BioResources, Italy	-	49	-	-	1	-	2	-	-	52
Department of Agricultural Research (DAR), Myanmar	-	-	-	-	-	-	-	-	-	48
DOA Genebank, Thailand	97	97	-	97	14	315	-	-	-	426
INRAE Centre for Vegetable Germplasm, France[A]	1299	-	-	-	663	326		-	-	2388
Faculty of Agricultural Sciences and Food, North Makedonia	-	35	-	-	-	-	-	-	-	35
National Agricultural Research Center, Jordan	-	32	-	-	1	-	-	-	-	35
Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Germany	41	53	2	-	7	4	2	-	4	129
National Plant Genetic Resources Centre, Zambia	-	-	-	10	2	-	-	-	-	12
Universitat Politecnica de Valencia, Spain	43	226	1	-	14	-	55	-	1	340
Agrifood Research and Technology Centre of Aragón (CITA – Aragón), Spain	4	136	-	-	-	-	-	-	-	140
Seed Savers Exchange, USA A	100	-	-	-	3	25	-	-	-	298
Centre for Genetic Resources, The Netherlands (CGN)	381	277	100	4	22	114	107	2	5	516
Plant Gene Resources of Canada	3	3	1	-	-	-	-	-	-	7
USDA/ARS, USA	-	-	-	-	-	-	-	-	-	870
Private breeder's collection, Egypt	-	5	124	-	10	-	-	-	-	139
IPGR-Sadovo, Bulgaria	34	19	19	-	-	1	-	-	-	75
Total	**7392**	**2649**	**879**	**184**	**2883**	**1404**	**281**	**26**	**21**	**17,190**

[A] Accessions provided under CV include commercial cultivars, old cultivars, local cultivars, and may also include landraces and breeding lines.

some collections are listed here that are not included in those databases, and some collections (like INRAE) have a greater numbers of accessions than reported to Genesys and WIEWS. Notably, not all respondents could provide detailed data, as not all accessions have been fully classified. The overall situation is that most of the accessions are cultivars (including heirloom cultivars) as well as local cultivars/landraces of brinjal eggplant (*S. melongena*) There are also many accessions from species in GP2 and GP3 for brinjal eggplant. These are mainly held in the collections at WorldVeg (1046 accessions), the ICAR-National Bureau of Plant Genetic Resources (1110 accessions) and the INRAE Centre for Vegetable Germplasm (500 accessions). Significant collections of African eggplants (*S. aethiopicum* and *S. macrocarpon*) are held at WorldVeg (569 accessions), the INRAE Centre for Vegetable Germplasm (400 accessions), the Centre for Genetic Resources, The Netherlands (114 accessions) and the CSIR-Plant Genetic Resources Research Institute in Ghana (83 accessions).

3.2 Conservation priorities and collection gaps

Further analyses were based on the responses of 27 respondents.

3.2.1 Primary conservation priority

In response to the question, "What are the primary conservation priorities of the collection?", 22 respondents checked "Local cultivars," 16 checked "Wild materials," 15 checked "Internationally important cultivars" and 14 checked "Breeding materials." The respondents had the option of selecting more than one option. Two respondents did not answer this question. It is clear that landraces are the conservation priority for the majority of the collection holders.

3.2.2 Conservation gaps

Eighteen responses were received to the question, "What are the known collection gaps?"

Five responses indicated a focus on CWR with answers such as: "Wild/uncultivated species, including *S. dasyphyllum*, *S. anguivi*, *S. torvum,*" and "Representation of species of wild or weedy *Solanum*, and collection of breeding materials of both the cultivated and the wild pools."

Four responses focused more on geographical gaps in collections, for example: "Ecogeographic gap," or more specific responses: "Caribbean region and S Africa," "European cultivars and broader representation of scarlet eggplant," and "Increase the collection with foreign materials." More general responses included "Collection gaps are not identified" and "We only hold a small number of eggplant accessions and they are not a priority crop for us." Some respondents referred to the quality of the existing collection, for example: "Material was collected in 1983 but the quality of seeds was not verified. The accessions are not regenerated." and "No fresh collections have been undertaken in a long time."

We obtained 12 responses to the question, "If any gaps are identified, is there a timeframe for filling them?" Seven responses were "No" or variations of "No," for example: "No, collection is done when funds are available" and "Depends on fund availability and institutional capabilities as per trained staff and facilities". Five answers included specific plans or timeframes, for example: "Explorations are planned to collect the gaps by involving all stakeholders of National Agricultural Research System (NARs)" and "Collection missions ongoing in South and Souteast Africa."

3.2.3 *Ex situ* and *in situ* conservation

Twenty survey respondents answered the question "Are there efforts to conserve eggplant *in situ* or *ex situ*?" Almost all of them focused on *ex situ* conservation, in the form of cold storage of seed packages, but some also mentioned *in situ* conservation of wild species:

> "*Ex situ* is more relevant here in seed banks yet on farm conservation and management is being practiced from time to time. As per the weedy species they are of least concern meaning there is no efforts in conserving them *in situ.*"

> "For wild species, there are current plans to conserve them *in situ*, resources permitting. For landraces (other species), *ex situ* conservation strategies are already in place, although there are serious limitations with regards to funding."

A combination of *ex situ* and on-farm conservation was also mentioned:

> "For *ex situ* conservation we regenerated the plant material to obtain a sufficient quantity of seeds that guarantees the long-term conservation, and we carry out periodic germination tests to guarantee the quality of the seeds. For *in situ* conservation, we attend seed requests to users interested in their cultivation."

> "Both. We have our seed bank, but we make many varieties available through our Exchange program so gardeners can request and grow and save seeds to share in the future."

3.2.4 Wild species

In response to the questions, "Do you have wild eggplant native to your country? Which species? And are they included in your collection?", 14 respondents replied "No" or "Not relevant" and five respondents did not answer. The remaining eight respondents were in countries where wild eggplants are present. The respondent from India noted that their collection includes *S. albidum, S. incanum, S. nigrum, S. erianthum, S. gigantum, S. kurzii, S. torvum, S. spirale, S. surattense* and *S. viarum*. The respondent from Ghana mentioned that *S. anguivi, S. dasyphyllum* and S. *torvum* are conserved in their collection. The respondent from Jordan highlighted that they are considered as weedy species, but are registered in local floras, and highlighted the following species that grow in Jordan: *S. coagulans, S. dulcamara, S. elaeagnifolium, S. incanum, S. luteum, S. nigrum, S. sinaicum* and *S. villosum*. The respondent from Zambia said that the possibility of finding wild eggplants is high, especially in protected areas, but that no surveys or collections have been undertaken yet.

3.3 Maintaining the collections

Seed Storage

In response to the question, "What are the seed storage conditions for the long-term storage?", most respondents (23 out of 27) noted that seeds are stored at −10°C to −20°C. One respondent noted that seeds are stored at 4°C and three did not answer the question. Regarding the packing material for long-term storage, 17 of the respondents use sealed aluminum bags or foil bags, five use glass jars or tins, and one uses brown paper bags. Four respondents did not answer this question. Regarding humidity, the responses included: "No humidity control, but seeds are dried to 3–7% moisture content" and "5% seed moisture content (by weight)." Some respondents mentioned humidity control (20–30% or 50%) in the storage room in addition to seed drying and sealing conditions.

3.3.1 Germination tests

When asked whether initial viability monitoring is practiced, 19 respondents replied "Yes," one replied "Yes, to 75%," two replied "On regeneration" and five did not answer.

Regarding periodic viability monitoring and its frequency, we obtained various responses. Most were in the categories of every 5 years, every 5–10 years, or every 10 years (Figure 3.1). One was more detailed: "First time after 25 years, then every 10 years." In the category "Others", some respondents gave less specific answers, for example: "It depends on the staff," and "Depends on capacity," and "According to the rules". One respondent replied, "Have not tested yet."

When asked how many seeds are used for germination tests, the majority used 50 or 100 seeds (Figure 3.1). Other responses were "Depends on rules" and "Typically 200, but we can do as few as 5 depending on inventory."

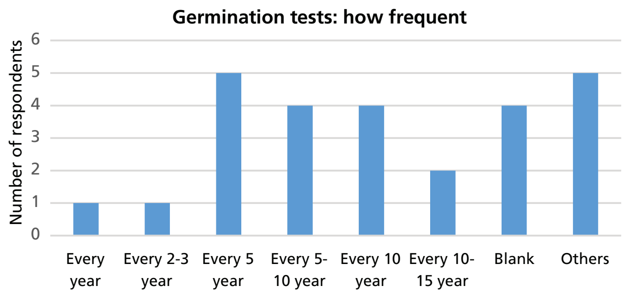
3.3.2 Regeneration of accessions

In response to the question, "How many plants are used per accession for regeneration/seed multiplication?", 11 respondents noted that they used more than 20 plants and seven reported that they use 10 or fewer (Figure 3.2).

In response to the question, "What measures are taken for isolation during regeneration/seed multiplication?", two respondents noted that they use no isolation measures and two did not answer. The other respondents (23 out of 27) replied that they use forms of isolation such as distance, net cages, bagging, insect-free greenhouses or similar.

3.3.3 Characterization

When asked if standardized methods are used for phenotyping the collection, four respondents said "No" and six did not answer the question. The



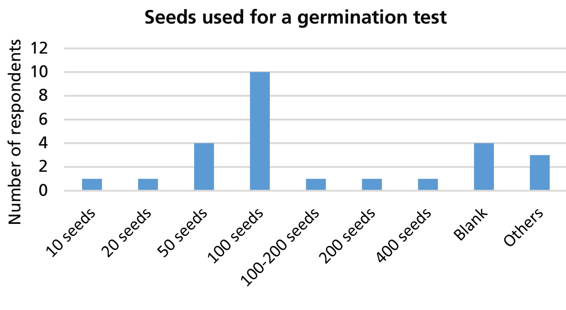


Figure 3.1. Respondents' answers to questions about the frequency of germination tests for eggplant seeds and the number of seeds per germination test.

majority (21 respondents) reported that they use some form of standardized method. The Bioversity International (formerly IPGRI) descriptor list for eggplants was the most common reference, but other references included the UPOV descriptors for eggplant, the minimum descriptor list from the ECPGR Working Group on Solanaceae, and institutions' own descriptor lists. For example, the collection in India uses the minimal descriptors of Agri-Horticultural Crops published by ICAR-NBPGR (Srivastava et al., 2001).

In response to a question on genotypic characterization, 11 respondents noted that no characterization has been done, and seven did not answer. The majority (20 respondents) reported that they are conducting, or have conducted, genetic characterization work. This work is typically undertaken as a part of specific projects. For example, the respondent from Universitat Politecnica de Valencia noted, "Genotypic characterization is performed according to the research projects in which the accessions are used." The respondent from WorldVeg noted: "Part of global G2P Sol collaboration." The use of various marker systems, such as RAPDs, AFLPs, expressed sequence tags, SSRs and SNPs, was mentioned.

3.3.4 Safety duplication of germplasm

We asked an open question "Describe the back-up status of the collection (type of back-up: secondary collection elsewhere, and percentage of accessions backed-up)". Five respondents did not answer this question. Four replied "Nil" or "Not currently backed up" or similar. Most, however, mentioned that accessions are backed up in another genebank. Seven specifically mentioned the Svalbard Global Seed Vault. Many did not specify the percentage of the collection that is safety duplicated (Figure 3.3).

When asked about barriers to backing up collections, the responses included:

- "This collection is not a priority"
- "Would require regeneration – not a priority species currently"
- "Germplasm regeneration of accessions with low seed amount"
- "Quantity of seeds"
- "Scarcity of human resources"
- "Funds and storage facilities"
- "Scarcity of funds and personnel"
- "Understanding of administrators, policy, etc."
- "Bureaucracy involved in the system"

Other respondents replied that there were no barriers; almost all of those respondents were from collections where the accessions are in fact already backed up.

3.4 Documentation and information

Table 3.3. provides an overview of the respondents' databases for documenting their collections, and includes information on data availability, website and language.

Of the 27 respondents, 19 have made passport data publicly available online. Four have not made passport data publicly available but will provide this information on request. The remaining respondents did not answer the question.

Five of the 27 collection holders have made phenotypic data publicly available online. Another 13 provide this information on request. Nine respondents did not answer the question. Ten of the 27 collection holders provide images of the accessions that are publicly available.

Only two out of the 27 collection holders have made genetic data publicly available, while another nine will provide those data on request. Only one collection holder provides information regarding on pathogen testing of accessions, while another nine will provide this information on request. Eighteen respondents did not answer this question.

The survey also asked about key publications (peer reviewed, popular press, online) on the eggplant collections. The responses are summarized in Table 3.4 with links and/or citations.

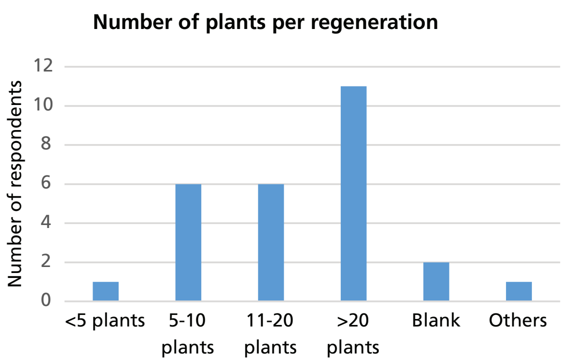


Figure 3.2. Respondents' answers to a question about the number of plants used to regenerate an accession.

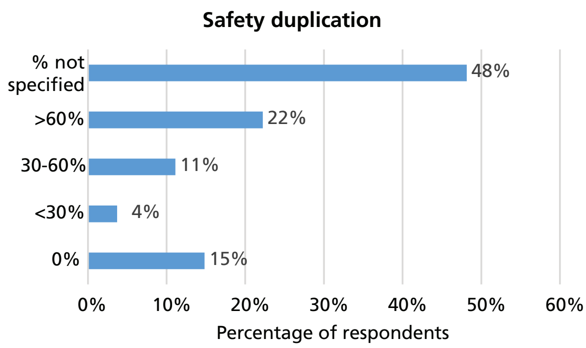


Figure 3.3. Respondents' answers to a question about the percentage of the eggplant collection that is safety duplicated.

3.5 Health of germplasm

3.5.1 Effects on conservation and distribution

When asked, "To what extent are pests or diseases having an effect on the collection, causing annual losses of accessions?", most respondents replied "Minor" or "No effect" (Figure 3.4). However, several organisms were highlighted in response to the more specific question, "What pathogens and diseases threaten the collection?" The respondent from Ukraine noted *Colletotrichum melongenae, F. oxysporum, Botrytis cinerea, T. urticae* and *Leptinotarsa decemlineata*. The respondent from Ghana highlighted *F. oxysporum, Colletotrichum* spp. and *Aspergillus* spp. The respondent from Italy mentioned *Pythium* spp., *Phytophthora* spp., *Verticillium alboatrum, Cercospora melongenae* and Alfalfa Mosaic Virus (AMV). The respondent from Myanmar highlighted eggplant shoot and fruit borer. The respondent from Seed Savers in the USA noted seed-borne diseases such as *Alternaria, Fusarium* and *Anthracnose*. The respondents from the USDA and WorldVeg highlighted viruses and/or viroids. Other respondents did

Table 3.3. Details on databases/data management systems for the respondents' collections.

Organization, Country	Database name and website (if public)	Language	Public
Banque Nationale de Gènes, Tunisia	GRIN-global, http://www.tn-grin.nat.tn/gringlobal/search	English	Yes
Institute of Vegetable and Melon Growing of NAAS, Ukraine	Passport database		No
World Vegetable Center, Taiwan and Tanzania	GRIN- Global, http://genebank.worldveg.org	English	Yes
ICAR-National Bureau of Plant Genetic Resources, India	PGR Portal, http://www.nbpgr.ernet.in/PGR_Databases.aspx	English	Yes
UK Vegetable Genebank, UK	MS Access (internal), Eurisco/Genesys (public)	English and others	Yes
N.I. Vavilov All-Russian Institute of Plant Genetic Resources, Russia	Passport database		No
The National Institute of Horticultural Research, Poland	GRIN-Global INHORT/EGISET, https://wyszukiwarka.ihar.edu.pl/en	Polish, English	Yes
Agroscope, Suisse	PGRFA-NIS, https://www.pgrel.admin.ch/pgrel/#/	More	Yes
Crop Research Institute, Czech Republic	GRIN Czech, www.vurv.cz	Czech, English	Yes
CSIR-Plant Genetic Resources Research Institute, Ghana	Excel, uploaded to GBIF (https://www.gbif.org/dataset/8d759514-5679-4f7d-b745-e75707c06bc9)	English	Yes
Institute of Biosciences and BioResources, Italy	Mediterranean Germplasm Database (MGD), https://ibbr.cnr.it/mgd/	English, Italian	Yes
Department of Agricultural Research, Myanmar		English	Yes
DOA Genebank, Thailand	Our own, We are going to do this		No
INRAE Centre for Vegetable Germplasm, France	Olga	French, English	Yes
the National Agricultural Research Center, Jordan	GRIN Global, www.narc.gov.jo	English	Yes
Leibniz Institute of Plant Genetics and Crop Plant Research, Germany	GBIS, http://gbis.ipk-gatersleben.de	German, English	Yes
National Plant Genetic Resources Centre, Zambia	SADC data management and information system (SDIS)	English	Yes
Polytechnic University of Valencia, Spain	Spanish National Inventory, http://wwwsp.inia.es/Investigacion/centros/crf/Paginas/InventNacion2.aspx	Spanish, English	Yes
Agrifood Research and Technology Centre of Aragón, Spain	Access (passport data) and Excel (characterization data) (1) EURISCO (European Search Catalogue for Plant Genetic Resources): https://eurisco.ipk-gatersleben.de/apex/f?p=103:1 (FAO code ESP027); (2) National Inventory (CRF-INIA): https://bancocrf.inia.es/es/ (Bank code ESP027); (3) Germplasm website: https://bghz.cita-aragon.es/	English, Spanish	Yes
Seed Savers Exchange, USA	Microsoft Access, Not public at this point. But we make our distributable varieties available here: exchange.seedsavers.org as Heritage Farm (IA SSE HF)	English	No
Centre for Genetic Resources, The Netherlands	GENIS, own developed oracle database, www.cgn.wur.nl, https://cgngenis.wur.nl/	English	Yes
Plant Gene Resources of Canada	GRIN-Global-CA, Not active at this time.	English, French	Yes
USDA/ARS, USA	GRIN-Global	English	Yes

not specify specific pathogens, or had no concerns.

Various responses were received to a question about the extent to which pests and diseases affect the distribution of accessions (Figure 3.4). The responses included: "European and international legislation can prevent distribution because the material is not always tested for requested diseases." and "Viroid and increased PC requirements hamper international distribution."

3.5.2 Plant health monitoring

In response to the question, "What pathogens are tested for in the collection?", 11 respondents did not answer, five replied that no testing is done, and 11 described some form of plant health monitoring. One respondent noted that all material is visually checked by the genebank staff during regeneration, looking for viruses and other diseases. Another replied that materials are tested before distribution but not before conservation. Some respondents specified tests for viroids, AMV, and *F. oxysporum*. Two of the respondents noted that tests are conducted if plants show symptoms in the field or during characterization.

When asked, "What are the phytosanitary/quarantine requirements for receiving new materials?", nine respondents did not answer, and three replied that no requirements are set. The majority of respondents referred to phytosanitary certificates from the country of origin and national regulations for seed import.

One respondent mentioned internal seed cleaning procedures, and two respondents mentioned quarantine-control of new materials. Another highlighted seed health assessment during germination tests. The respondent from WorldVeg responded: "Viroid testing, plant health inspection, and regeneration under quarantine conditions."

The respondent from India provided the following answer:

> "Phytosanitary certificate is to be issued from source country. Import of new material will be processed as per the Plant Quarantine (Regulation of Import into India) order 2003. It is tested for Pest Free Conservation Status by Plant Quarantine Division, before release or conservation."

In response to the question, "What percentage of the accessions are pathogen tested?", nine respondents did not answer, and six noted that no accessions have been tested or they did not know if testing had been conducted. One respondent replied, "The accessions are only tested when delivered to countries with phyto requirements." Four respondents had tested half or less (5–50%) of their accessions. Three respondents had tested more than half of their accessions (50–100%). One respondent noted that all new materials entering the genebank are tested.

When asked, "What percentage of the accessions are cleaned-up?", 15 out of the 27 respondents did not

Table 3.4. Details on the key publications from/involving respondents' collection.

Collection	Details
World Vegetable Center, Taiwan and Tanzania	Taher et al. (2017); Taher et al. (2019), Stoilova et al. (2019), Rakha et al. (2020)
ICAR-National Bureau of Plant Genetic Resources, India	Gangopadhyay et al. (2010)
Agroscope, Switzerland	Zollinger (2021)
CSIR-Plant Genetic Resources Research Institute, Ghana	Aboagye and Smart (2019)
The National Agricultural Research Center, Jordan.	Fikret et al. (2013); Kiran et al. (2019)
Centre for Genetic Resources, The Netherlands	Old ECPGR Solanaceae working group reports. The whole collection has been genotyped by G2P-SOL project, and this information is in the process of being published.

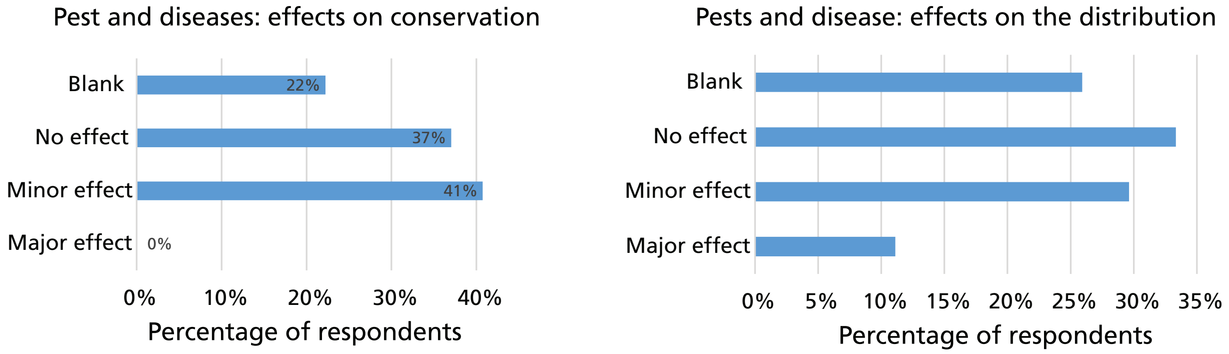


Figure 3.4. Respondents' perceptions of the effects of pests and diseases on conservation and distribution, respectively.

respond or did not know. Three respondents said that no accessions have been cleaned. Four respondents said that less than half of the accessions have been cleaned (5–50%) and three respondents said that more than half (50–100%) have been cleaned. One respondent noted that only accessions that will be distributed are cleaned.

3.6 Distribution of germplasm

In response to the question, "How many eggplant accessions are distributed per year?", the answers varied from 0 to 503 accessions. The WorldVeg international collection distributes the most accessions, because it includes seed kits distributed to African small-scale farmers. In this initiative, 2472 samples have been distributed annually in recent years from 503 accessions. Most collections distribute fewer than 10 accessions per year (Figure 3.5).

When asked how many unique recipients receive eggplant materials per year, the responses ranged from 0 to more than 100. Many respondents did not provide a number.

For an open question on what types of agreements/permits are necessary for distribution, the majority (14 of the respondents) replied that they use a standard material transfer agreement (SMTA), five were blank, and others provided more vague responses: for example, "material transfer agreement" or "agreement with the director" or similar.

Another question addressed distribution policies; that is, to whom accessions are distributed. All collection holders except one distribute materials for use in research and breeding (Table 3.5). One respondent noted that they do not distribute materials for such purposes, and commented, "The quality and quantity of seeds are not verified." The majority of the collection holders also distribute materials to the public. Among limitations to distribution were, "Seed stocks do not currently permit distribution of the very small number of accessions which we hold" and "An active collection of vegetable crops including eggplant is being developed. The eggplant accessions will be available for distribution probably in 2023."

Comments about distribution to other groups included, "Only to public when results are sent back," and "To students and farmer-based organizations," and "To students and lecturers in colleges and universities."

A more detailed question was asked about the intended use of the distributed accessions. Each collection holder was asked to specify how frequent a given purpose was provided (frequent, moderate, rare or never). The most frequent intended uses of distributed materials were plant or pathogen research, followed by breeding and phenotypic evaluation (Table 3.6). Propagation for resale and for certification programs were the least frequent intended uses of distributed eggplant accessions.

When asked about the distribution costs to the recipient, 13 respondents replied "No cost", seven specified a cost, and seven did not answer the question. The collections that charge the recipients provided the following details:

- "Phytosanitary certification costs only"
- "Locally nothing and overseas to be paid by the recipient"
- "15 euros/accession if more than 10 accessions requested"
- "Depends on seed requests and amount of accessions. Between 2 and 30 USD per accession"
- "1 variety is $3 US dollars for shipping, and all phyto-certificates and import permits need to be paid for by the requestor"

Table 3.5. Distribution policy: number of respondents distributing seeds for use in research, breeding and industry.

	Research	Breeding	Industry	Public
Yes	23	23	10	17
No	1	1	10	6
Blank	3	3	7	4

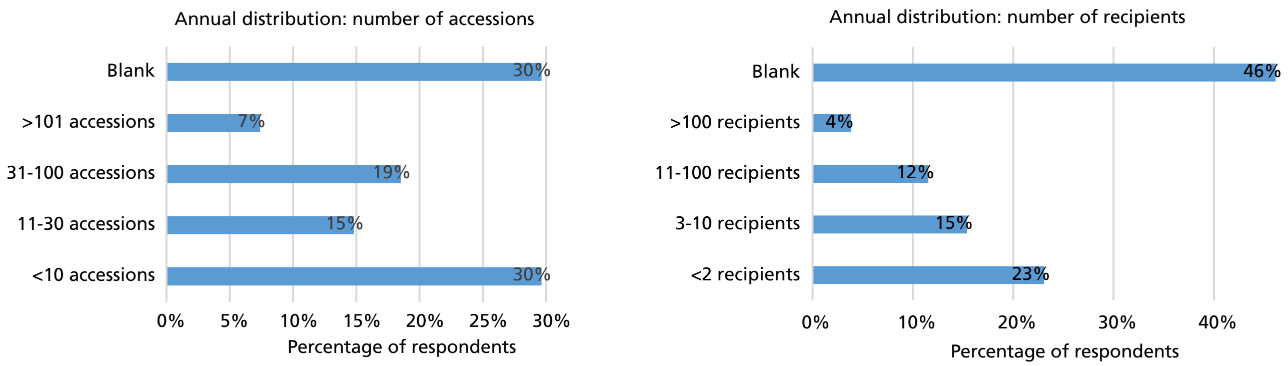


Figure 3.5. Annual numbers of distributed eggplant accessions and recipients, as specified by respondents.

When asked about the proportion of materials distributed to domestic recipients out of total recipients, 11 noted more than 70%, two noted 50%–70%, two noted 20%–49%, and two noted less than 20%.

3.7 Internal use within the organization

The survey asked about internal uses of the eggplant collection by the collection holders. The possible responses were; frequent, moderate, rare or never. Some respondents did not answer these questions. The most frequent internal use was for phenotypic characterization. Use in molecular characterization and genomics, and for pre-breeding and breeding, was not common for most of the 27 respondents (Table 3.7). The respondent from CGN in the Netherlands replied, "CGN is not conducting research, it is always done together with third parties using our collections." At WorldVeg, the internal uses of eggplant germplasm include breeding of African eggplant and rootstock selection for tomato grafting. Eggplant pre-breeding is conducted on a project basis, with the support of the Crop Trust, and the G2P Sol collection is being? morphologically characterized.

3.8 Human resources and finance

3.8.1 Organization structure and ownership

When asked about the organizational structure of their institute, 14 collection holders replied that they are part of a larger organization, either a university or a governmental organization, while 11 replied that they are independent organizations. Two respondents did not answer this question.

When asked about financing, 18 respondents replied that they are financed by the government to 90%–100%, two replied that they are financed to 100% by the larger organization (university or governmental institution), three replied that they are financed by the government to 50%–80% with the remaining 20%–50% from projects or private donors, and one replied that it is 100% privately financed by an non-governmental organization. In response to the question about legal ownership, 25 out of 26 noted that their collection belongs to the holding institute or the larger organization they are a part of (usually a university or governmental institution). One respondent did not answer this question.

When asked whether the collection is subject to the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), 19 respondents replied "Yes", six replied "No", and three did not answer this question.

3.8.2 Human resources, training and scientific network

When asked whether there is a person with specific knowledge dedicated to eggplant conservation/curation of the collection, 12 respondents replied "No," 12 replied "Yes," and three did not reply.

Table 3.6. Intended uses of distributed eggplant accessions: number of respondents in each category for frequency of intended uses.

External use	Frequent	Moderate	Rare	Never	Blank (no answer)
Plant and/or pathogen research	6	2	4	5	10
Phenotypic evaluation	4	6	4	3	10
Molecular characterization	2	5	2	7	11
Genomics	2	2	3	8	12
Pre-breeding	3	5	3	6	10
Breeding	5	4	3	4	11
Propagation for resale	0	2	4	8	13
Certification programs	1	1	4	10	11

Table 3.7. Internal use of eggplant accessions: number of respondents in each category for frequency of each use.

Internal use	Frequent	Moderate	Rare	Never	Blank (no answer)
Plant and/or pathogen research	5	5	3	7	7
Phenotypic evaluation	9	7	3	3	5
Molecular characterization	3	5	6	7	6
Genomics	3	1	3	12	8
Pre-breeding	4	3	1	11	8
Breeding	5	1	6	10	5
Propagation for resale	3	0	2	14	8

The proportion of time the dedicated person spends on eggplant varied from 0–10% of a full-time position (four respondents), to 10–25% (four respondents), 25–50% (three respondents) and >50% (two respondents). Fourteen respondents did not answer this question.

When asked an open question about the type of constraints (if any) affecting the conservation of eggplants related to staff numbers, we received 12 responses, including the following:

- "Insufficient staff for the entire genebank, including eggplants"
- "The staff number in the genebank is insufficient to do all activities (collecting, cleaning, viability control, regeneration, characterization, documentation, etc.) related to GR"
- "4 professional staff, 2 technicians, available for the entire genebank collection"
- "Limited staff particularly technical/ field officers"
- "Well trained staff are lacking especially for the wild collections"
- "Retirement of the expert on eggplant"
- "Our capacity is limited by the field space we have which correlates to the number of seasonal staff recruited to help grow for regeneration"

We received few details of constraints related to training, but two responses were: "No staff specifically trained for the exercise" and "Well trained staff are lacking especially for the wild collections."

When asked if the collections were part of an international network or research projects, 20 respondents replied "No," six replied "Yes" and one did not answer this question. The networks mentioned are as follows:

- G2P-SOL, an ongoing Horizon 2020 project
- The ECPGR Solanaceae Working Group, an established European genebank network with some participants from outside Europe.

Some respondents mentioned the previous European Union project EGGNET, in which various collection holders collaborated to improve eggplant conservation in Europe. Although this project stopped long ago, European collection holders still benefit from it, and are acquainted with each other from their time working on the project.

3.8.3 Budgets

Several respondents mentioned budget constraints, for example:

- "Insufficient budget for the entire genebank"
- "Budget restrictions limit the total number of regenerations for all crops"
- "There is always a problem of budget allocated for all collection missions as whole and for characterization".

When asked whether budget constraints will result in a loss of germplasm, eight respondents replied "Yes" (or similar), nine replied "No" (or similar) and 10 did not answer the question.

Other responses about constraints to replanting or maintaining the collections included:

- "Regeneration backlog"
- "We hold multiple crops, for several crops we are a recognized global base collection. These take priority over eggplant unfortunately. Our physical capacity is limited."
- "Limited capacity due to inadequate staff and financial resources"
- "Some needs like infrastructure and facilities for propagation especially controlled environment"

Some respondents noted other constraints, for example: "Our budget allows us to address conservation tasks like regeneration and characterization, control of viability or seed request, but we do not have the capacity (budget, staff, etc.) to disseminate, disclose and update the information of the collection." and "Insufficient funds for viroid testing."

3.9 Long-term sustainability of eggplant conservation

3.9.1 Sustainability of collections

We asked the collection holders to describe the major needs or concerns influencing the long-term sustainability of the collection. Their responses included the following:

- "Sustainable funding"
- "Need to characterize for enhancing utilization in the crop improvement programs"
- "Eggplant is a very minor component of the collections at []- we may be able to regenerate in the future but it would be good to ascertain the global value of our accessions to determine if they represent unique and valuable diversity or are represented in other collections."
- "There is a need for inventory and seed evaluation of vegetable genetic collections at [the institute]. The activity is in progress. The whole collection will be regenerated, and both base and active collections will be created, as well as backup samples."
- "Space for storage. Sustainable power supply"
- "Insufficient staff"
- "Need young people"
- "Storage condition needs and budget for rejuvenation seeds for every year"
- "We need enough budget to maintain our Genebank"

- “Better recognition of the resources by the wider scientific community and in research programs”
- “Still base storage is not installed but looking forward to have it soon”
- “Adequate staff and resources to manage the collection”
- “Budget is insufficient but the long-term sustainability is ensured”
- “Major needs include more seasonal field staff to increase the number of varieties we can grow annually”
- “New emerging diseases and phyto legislation can influence the availability and regeneration of the collection”
- “Greenhouse space is at a premium in our facility and eggplant requires this for secure regeneration.”

Three of the respondents replied, “No needs.”

3.9.2 Sustainability of eggplant conservation on a global scale

Finally, when asked what changes to the present situation do you consider to be essential for the long-term conservation of eggplant at a global level the responses included the following:
- “Sustainable funding”
- “Better sharing of information”
- “For collections like ours, it’s important to understand if the small number of accessions we hold add to the conserved genepool diversity - better understanding and communication between collections.”
- “Social balance”
- “No changes necessary”
- “Sustainable funding, state of the art storage facilities/modern equipment, regular capacity building of staff on best practices and emerging issues/technologies”
- “Greater collaboration among all the institutions that preserve this germplasm”
- “Collaboration with other International Eggplant Organization to conduct research”
- “Availability of storage facilities”
- “Investment in surveys, collection, conservation, documentation, utilization, characterization and evaluation of the germplasm”
- “Higher implication of the [] Government”
- “Genebanks must be financed in the long term, to cover all their needs, including conservation tasks, but also optimizing and facilitating the use of stored plant materials.”
- “Eggplant is likely more popular in other countries globally compared to the United States. So educating people about eggplant, the usage, and history is critical to distribute.”
- “Better overview of really conserved and AVAILABLE germplasm. Material entered in regional/global databases is often not present or available. With this knowledge a better strategy for conservation can be made.”

3.10 Summary

This chapter summarizes the survey results. The online questionnaire was sent to institutions conserving eggplant materials and 28 of the completed surveys had sufficient information to be included in the analyses. The results were circulated, and each collection holder was invited to two consultation meetings to discuss the details and the way forward.

The results show that some collection holders do not (yet) report to Genesys or WIEWS. Furthermore, there are gaps in important passport descriptors, especially the biological status (SAMPSTAT). This descriptor tells if an accession is a cultivar, a landrace, a breeding line or wild. During the consultation meetings, it became clear that one reason for leaving the descriptor open was that it is hard to know if an accession is an old cultivar or a landrace.

The survey results reveal a mixed picture of management practices. Different procedures are used, both in the number of plants per regeneration, and in the number of seeds per germination test. Regarding conservation status, some collection holders are on track with safety duplication and the generation of sufficient seeds for distribution; others have severe backlogs in regeneration and in safety duplication and germination tests. Backlogs in the regeneration and safety duplication of landraces and cultivars were mentioned. Some accessions are not available for distribution as they are not pathogen-free. Many collections specifically noted that CWR are a challenge, because many are perennials and are time-consuming and difficult to regenerate. They also tend to have specific requirements for pollination or other issues that need special attention. One of the main reasons for such problems is a shortage of funding and human resources. Other constraints identified include access to relevant expertise, and plant health issues, with seed-borne diseases such as viroids and viruses hindering distribution. Collaboration and knowledge sharing were mentioned as opportunities. Collaboration with the breeding industry for regeneration was identified as an area to be strengthened. Other opportunities identified include webinars, a common platform for information sharing, and exchange of experience among institutions.

Eggplant regeneraton greenhouse. Photo: Maarten van Zonneveld

4 RECOMMENDATIONS

4.1 Elements of the global strategy

4.1.1 Main aim and process

The overall aim of the global strategy is to improve the quality of eggplant collections around the world and to facilitate the exchange and use of this diversity. The strategy aims to move towards a global eggplant collection that is securely safeguarded and easily available to current and future users. This global eggplant collection constitutes accessions held by different collection holders. The aim is for all these dispersed accessions to be stored safely in the long term, with appropriate back-ups, and for collections to be adequately curated, without unnecessary duplicates, and fully documented. All passport, characterization, and evaluation data should be searchable in Genesys. Another aim is to establish a global Eggplant Knowledge Platform with information relevant to the conservation and use of eggplants and their CWR.

The strategy development was initiated by the Crop Trust. It follows the structure and methodology as established by the Crop Trust from 2010 onwards, and the strategy is part of a larger update of conservation strategies for a series of globally important crops. This is the first strategy of its kind for eggplant. It is built on knowledge gained from a literature review (Chapter 1), an overview of current collections (Chapter 2), and additional information obtained from curators and genebank managers as obtained from the survey (Chapter 3). Thereafter, two consultation meetings with the survey respondents were especially valuable to summarize the results and identify key issues for the strategy to address. A draft strategy document was circulated to all 32 survey respondents for feedback before the final document was accepted.

4.1.2 Key players in eggplant conservation

As identified in previous chapters, most institutions involved in eggplant conservation and use are located in major eggplant-producing regions in Asia, Southern Europe and Africa. There are also breeding research and improvement programmes in eggplants in those regions. Recent overviews of eggplant breeding and institutions are provided by Kumar et al. (2020) and Rakha et al. (2021).

Important national collections include those at the National Bureau of Plant Genetic Resources (India), the National Genebank for Vegetable Germplasm Resources (China), the Polytechnic University of Valencia (Spain), the National Centre for Genetic

Resources and Biotechnology (Nigeria) and the Plant Genetic Resource Centre (Uganda) (Table 4.1). There are also key players in eggplant conservation in Northwestern Europe and in the United States. These are institutions with a strong emphasis on supporting international breeding and research, and that often have a global outreach. Examples include CGN (the Netherlands), INRAE (France), IPK (Germany), and USDA (USA). Several botanic gardens, such as the Royal Botanic Gardens (RBG) Kew (UK), also hold important collections. VIR (Russia) is another important player in the conservation and use of eggplants and holds a significant collection. WorldVeg in Taiwan and Tanzania has the second largest eggplant collection in the world, and its materials are available under the SMTA.

While these large collection holders, including several with global outreach, will play an important role in the global eggplant collection and conservation, the small collection holders that account for the majority of the 109 involved could play a local significant role by safeguarding national varieties, backing-up these accessions in larger collections, and connecting those requesting seeds to a the larger network of genebanks that constitute the global eggplant collection. Small collection holders that consider their level of expertise and interest in conserving eggplant accessions to be low may also consider donating their accessions to larger collection holders with more experience and expertise.

4.1.3 The rationale

The proposed strategy indicates priority themes or activities based on the constraints faced by curators and genebank managers, or identified by surveys of the literature and germplasm databases. This strategy is the first of its kind for eggplant. It places the conservation and use of, and access to, eggplant diversity in a global context. This is because food security and nutrition for many countries relies on crops bred using genetic resources outside their region (Khoury et al., 2016). Brinjal eggplant (*Solanum melongena*) has

Table 4.1. Institutions preserving more than 100 eggplant accessions

Geographical area and organization	Location
International organization	
World Vegetable Center (WorldVeg)	Taiwan and Tanzania
Asia	
National Bureau of Plant Genetic Resources	India
National Genebank for Vegetable Germplasm Resources	China
NARO Genebank	Japan
Bangladesh Agricultural Research Institute	Bangladesh
Plant Genetic Resources Centre	Sri Lanka
Uzbek Research Institute of Plant Industry	Uzbekistan
Plant Genetic Resources Department	Turkey
Africa	
Kafrelsheikh University	Egypt
Plant Genetic Resource Centre	Uganda
National Centre for Genetic Resources and Biotechnology	Nigeria
Europe	
Centre for Genetic Resources, The Netherlands	The Netherlands
Millennium Seed Bank Project, RBG Kew	United Kingdom
INRAE Centre for Vegetable Germplasm	France
N.I. Vavilov All-Russian Institute of Plant Genetic Resources	Russia
Institute of Vegetable and Melon Growing	Ukraine
Polytechnic University of Valencia	Spain
Scientific Centre of Vegetable and Industrial Crops	Armenia
Institute for Plant Genetic Resources	Bulgaria
Agrifood Research and Technology Centre of Aragón	Spain
Leibniz Institute of Plant Genetics and Crop Plant Research	Germany
Research and Development Institute for Vegetables and Floriculture	Romania
America	
USDA-ARS, Griffin, Georgia	USA
Embrapa Hortaliças + Embrapa Recursos Genéticos e Biotecnologia	Brazil

become a global crop. Its center of origin is in South and East Asia, while most of its wild relatives are in Africa. The importance of African eggplants (*Solanum aethiopicum* and *Solanum macrocarpon*) is increasing. For instance, WorldVeg and a few seed companies have started breeding programs for these crops. These should not be neglected.

4.1.4 Structure

We recognize the financial, human resources and time constraints faced by many collection holders. Therefore, we have attempted to develop a strategy that optimizes the use of existing resources. Additional funding will be targeted towards collaborations to achieve common goals to help collection holders improve the conservation and quality of their collections, and to create a global eggplant collection.

The strategy includes the following priority activities:

1. Establish a global eggplant working group. The working group shall have representatives from key collection holders and from breeding and research institutions. This group will be responsible for the progress in implementing key activities for a global eggplant collection.
2. Develop an Eggplant Knowledge Platform (EKP). The platform could be a web page and should include management practices such as regeneration protocols for CWR, seed treatments, and contact information for ongoing projects or activities involving eggplants. The Crop Trust could have the responsibility for the platform.
3. Improve passport data accuracy and completeness in the collection holders' databases to facilitate large-scale gap identification and screening for duplicates within and among genebanks.
4. Facilitate and encourage collaborative plant health-related activities, and develop a framework of protocols and management practices to address and reduce the risks associated with seed-borne diseases, including viruses and viroids.
5. Support collaborative activities associated with accession regeneration and safety duplication to reduce backlogs, and help to make all accessions available to users.
6. Characterize the global eggplant collection morphologically and genetically to enhance the use of the collection and making a global core collection of brinjal eggplant.
7. Encourage collaborative efforts to involve CWR in breeding programs, including the screening of CWR for useful traits in pre-breeding. This activity will seek support from public-private partnerships with long-term commitment and funding.

4.2 A global eggplant working group and knowledge platform

We recommend that a collaborative working group be instituted with the aim to establish a global eggplant collection across several genebanks, aligned to a knowledge platform.

A global collection shall be stored according to international FAO genebank standards, with its information and materials fully available to users under a SMTA. We recommend to establish a peer working group to achieve these goals. On a global level, the World Vegetable Center could play key roles in supporting *ex situ* conservation and facilitating this working group and in information sharing among countries and members. We suggest to build this working group using an established structure. The ECPGR Solanaceae Working Group, which includes European institutions, WorldVeg, and other international agricultural research institutes is an appropriate model. This group includes a range of institutions, and the strength of the ECPGR network is that it includes both large and smaller institutions involved in plant genetic resources conservation and use. The G2P-SOL project that links the genetic resources, genomes and phenotypes of Solanaceous crops has emerged from this collaboration.

In Southeast Asia, WorldVeg has had an influential role in collaboration with the ASEAN – AVRDC Regional Network on Vegetable Research and Development (AARNET) to conserve the genetic resources of brinjal eggplant and other Asian vegetables.

In sub-Saharan Africa, WorldVeg has collaborated with national partners from countries that have been identified as biodiversity hotspots for African vegetables. Landraces and CWR of African and brinjal eggplant, as well as leafy nightshade species, are among the African vegetables that have been conserved (van Zonneveld et al., 2021). This has been achieved with the support of the Taiwan Africa Vegetable Initiative. Furthermore, WorldVeg supports companies that breed and produce seeds of African eggplants. These companies are members of the Africa Vegetable Breeding Consortium.

Another influential project is the Crop Wild Relative Project, which was finalized in 2021, coordinated by the Crop Trust. Several missions to collect eggplant CWR were conducted between 2013 and 2019 in the Americas, Africa and Asia. The eggplant CWR obtained in these missions are currently being regenerated, characterized, and genotyped by WorldVeg in collaboration with RGB Kew, with the support of the Taiwan Africa Vegetable Initiative.

We suggest a common online site to house information relevant to eggplant conservation and use. This is not intended to store information such as passport data or characterization/evaluation data, but rather for protocols and management suggestions/notes. The site would have a page that lists upcoming events, publications of interest, best management practices, e.g., with a focus on issues of special interest to eggplant curators. Such issues include the regeneration of species from the eggplant genepools, including CWR, identification of these crops, protocols for seed germination and seed treatment, and protocols for viroid/virus elimination/control. This page would need to be updated and managed and responsibility clarified to make it feasible. The platform should be developed in collaboration with the working group and the institutions involved in the different activities. The work needs funding to be established and maintained, and if funded, the structure of the page should be discussed in advance, and then basic information can be added when available. The protocols for seed treatment, the management and identification of eggplant CWR and regeneration can be added and updated as necessary.

Based on the results obtained from various activities (as described below), updates on the EKP will be made by the working group. This will be an ongoing effort that will take place as new knowledge, such as guidelines for gap analysis and duplicate screening, is obtained.

4.3 Data updates, gap analysis and duplicate screening

Our analysis of eggplant data in Genesys indicated that many of the current accessions have no or little information about their biological status (SAMPSTAT). This means that it is not possible to determine if an accession is a cultivar, a landrace or a modern breeding line. Genotyping may provide information about the genomic background and/or identify which group each accession belongs to, but this requires further research on the genomic background of eggplant landraces. Furthermore, accessions are often missing information about the country of origin, georeference coordinates and other collection site information. For CWR and landraces, such information is important for gap analysis and for promoting their use. Genesys lacks data from several of the large eggplant collection holders. Some collection holders have added data to the Global Biodiversity Information Facility (GBIF) or WIEWS instead, or store it on their website or in a local database at their institution.

We suggest to divide this activity into different steps:

1. Complete passport data in each collection holder and upload these data to Genesys;
2. Add characterization and evaluation (C&E) data to Genesys;
3. Add genomic and high-throughput phenotyping data to Germinate in coordination with other platforms;
4. Conduct gap analysis for targeted collections for specific species and in specific geographies; and
5. Screen collections for possible duplicates.

Addition of more complete passport data

The first step to assemble updated passport data is that all collection holders complete the passport data uploads to their databases as much as possible. Ideally, passport data for all eggplant accessions should be available in Genesys. This would provide an overview of the entire genetic resources of eggplant and its CWR, and facilitate gap analysis and the identification of duplicates. Only collection holders can add data to Genesys. They should be encouraged to do so, and supported as necessary.

Addition of C&E data to Genesys

The majority of collection holders have made passport data publicly available. However, this is not the case for C&E data. We suggest to put more data online, because increasing data searchability will facilitate the use of the plant materials. At present, there is no descriptor list, and only one C&E dataset on eggplants, in Genesys. This dataset contains information on biotic stress resistance of accessions from the WorldVeg genebank collection and includes two traits: susceptibility to grasshopper (*Amrasca bigguttula*) and susceptibility to cotton aphid (*A. gossypii*). The C&E facility at Genesys is new, so the lack of data for eggplants is not surprising. A first step to increase the use of this facility would be to encourage collection holders to send C&E datasets to Genesys. Many, however, will need support to do this.

Addition of genomic and high-throughput phenotyping data to Germinate in coordination with other platforms

The Crop Trust has supported CWR Project partners to share genomic data on pre-breeding lines on Germinate, which is managed by the James Hutton Institute. The G2P Sol project has uploaded genomic data of the genotyped eggplant accessions to the Phenome Network. An information management structure needs to be developed and agreed upon to manage genomic and high-throughput phenotyping data from the different platforms in a coherent way and to make this information accessible to users.This should be complemented with training of users from different countries and regions to unlock the potential of these resources for a wide range of users.

Gap analysis

The survey showed that more than 35 wild species are conserved in germplasm collections, although some have only a few accessions. For example, two eggplant relatives, *Solanum rigidum* and *Solanum lidii* have very few conserved accessions while they are endemic to respectively Cape Verde and the Canary islands, and are respectively red listed as Vulnerable and Critically Endangered. Other eggplant CWR are not conserved at all. We recommend a thorough gap analysis for the global collections of eggplants to tailor new collection missions.

Screening for duplicates

Screening for unwanted duplicates can be facilitated by access to accurate and complete passport data. Duplication can occur between collections and within collections. An accession with an identifier that is received twice from the same donor is a duplication that can be readily removed if both are viable and available for distribution worldwide. However, complete passport data is important to identify duplicates. Accessions may have the same name, but different characteristics. For example, if the material is regenerated under different conditions, it is not a duplicate. Therefore, it is important to include C&E data in duplication analysis. Genotyping data, with its limitations, can also be applied in this process. The newly introduced digital object identifier (DOI) tagging of accessions could also be useful for screening for duplicates.

In some cases, accessions that are accessible in one collection could be removed from another, with permission of genebank management. In Europe, AEGIS has adopted this approach based on mutual trust. Establishing a similar degree of collaboration outside Europe could help to reduce overall conservation costs. The first step towards reducing unwanted duplication in genebanks is to discourage them from requesting accessions from other genebanks simply to increase the size of their own collection, if the original accession is secure and easily available elsewhere. However, given changing national and international phytosanitary and germplasm access regulations, sometimes it makes sense for a national genebank to have a copy of potentially useful accessions stored locally, rather than continuously requesting them from abroad.

4.4 Collaborative activities on plant health issues

Because eggplant resources are distributed as seeds, the problem of seed-borne diseases must be addressed. Curators have reported that phytosanitary regulations, import and export restrictions, and increasing paperwork and associated costs are challenging. This is especially true for international seed exchange. Quarantine pathogens such as viruses, viroids and phytoplasmas are of particular concern.

Many viruses, viroids and phytoplasmas infecting eggplant seeds have been identified, though that is not the case with the less domesticated forms (i.e. African eggplant) or with eggplant CWR. In addition, most of the viruses listed in Table 1.2 result in readily detectable symptoms on eggplant. However, it is also likely that eggplant serves as a host for latent viruses that remain undetected by visual examination, but are a source of inoculum for transmission to other crop plants, such as tomato or pepper. For example, eggplant can be carrier of tomato chlorotic dwarf viroid (TCDVd) and remain asymptomatic, but it can infect tomato, leading to serious disease symptoms in this crop (Gramazio et al., 2019b). For this reason, it is recommended to implement measures to eradicate this and other viroids. WorldVeg, for example, routinely tests eggplant germplasm before distribution to users. The tests target seven common viroids in Solanaceae: potato spindle tuber viroid, pepper chat fruit viroid, tomato apical stunt viroid, TCDVd, tomato planta macho viroid and columnea latent viroid.

Routine testing is conducted to detect common pathogens, and further tests are also required to reduce false negatives resulting from small seed samples. In addition, chemical and heat-based seed treatments have been proposed to systematically clean seeds, eradicating other pathogens that have not been tested for. However, as well as incurring extra costs, such methods can affect seed longevity. For example, a heat treatment (72 h at 70–76°C) to eliminate pathogens from C*apsicum* seeds resulted in a substantial reduction in seed vigor (Rast and Stijger, 1987). A TSP/HCl treatment was found to significantly reduce seed vigor and germination in about one-fifth of the seed lots of the USDA C*apsicum* collection (Jarret et al., 2008). An alternative chemical treatment, Na_3PO_4 for a maximum of 2 hours, did not detrimentally affect capsicum seed germination (Rast and Stijger, 1987). However, it is unknown how such treatments affect eggplant germination of seed longevity.

At present, genebank practices related to plant health vary greatly among collection holders. Another concern is how to absorb or get reimbursed for the additional costs associated with tests and procedures undertaken to address phytosanitary issues. Working together to find reasonable and practical solutions would be the first step. It would be sensible to hold virtual meetings or discussion groups to update guidelines and procedures.

The sharing of knowledge and experience in how to clean seeds and manage collections to avoid and/or eliminate viroids and viruses is now a high priority. Collaboration in the form of sharing protocols and experiences, and also applying for external research project support to address these issues, are desirable. Research priorities might include the development of recorded video training sessions, and using artificial intelligence in conjunction with digital imaging and a reference library to identify specific pathogens based on symptomology. These activities would be integrated within the EKP.

We suggest the following tasks:
1. Promote the acquisition, validation and sharing of information related to seed cleaning protocols and associated equipment.
2. Collaborate on seed research to assess the impact of seed cleaning protocols on seed viability and longevity.
3. Collaborate in the establishment of standardized seed treatment protocols to eliminate viruses/viroids and phytoplasmas from seeds.
4. Develop cooperative research efforts to detect and identify viruses/viroids and phytoplasmas in eggplant CWR.
5. Collaborate on the evaluation of eggplant CWR as sources of resistance to viruses and viroids.
6. Collaborate on the development of a digital database (reference collection) of photographs of pathogen-infected eggplant for diagnostic purposes.
7. Collaborate on the detection of latent viruses in eggplant, and evaluations of their potential to harm other crops.
8. Discuss and promote the evaluation and use of emerging technologies for pathogen detection, identification and elimination.

4.5 Collaborative activities on regeneration and safety duplication

Here, we suggest a collaborative effort to safeguard eggplant global diversity. We recognize the responsibility of each country to conserve crop diversity within their borders, but we suggest that collaborations could strengthen that work. Collaborations can include both new collecting missions (to fill identified gaps) and also regeneration and safety duplication.

This work will increase the percentage of available accessions by ensuring that sufficient seeds are available for distribution.

We suggest the following tasks:
1. Develop standard operating procedures (SOPs) with agronomic and biological guidelines to regenerate different eggplant species, including CWR. These guidelines should include crop management, disease management, how to evaluate phenological characters, and treatments to stimulate flower and pollen development and fertilization in the case of CWR.
2. Collaborate with the seed industry to regenerate materials in genebanks.
3. Strengthen the AARNET network in Southeast Asia.
4. Strengthen collaboration on the regeneration of CWR.
5. Support collaborations to implement safety backups.
6. Identify fundraising opportunities.

Collaboration with the seed industry for regeneration

Breeding companies and the seed industry can provide in-kind support for the seed multiplication of cultivars and landraces. This would represent a substantial contribution to reducing regeneration backlogs. Seed companies, and their associated breeding programs, are typically well equipped and organized to produce high-quality seeds in a range of environments. The seed companies could keep half of the multiplied seeds and share the other half with genebanks. They also often have experience dealing with a range of diversity, the control of pests and pathogens, and seed cleaning and processing. In these types of collaborations, seeds are shared with seed companies under the SMTA. Genebanks such as CGN have collaborated with the breeding industry for more than 20 years. Companies are requested to regenerate new materials, those with few seeds, and those whose seeds have a low germination rate. The companies offer this service in kind, because they benefit from having access to material for their own breeding programs. Collaborations can be bilateral or multilateral; for example, WorldVeg collaborates bilaterally with some seed companies and multilaterally with Taiwanese seed companies in an initiative called Rescuing Seed Together. As of December 2021, this initiative included seven seed companies and one public partner in a collaboration to multiply seeds. The staff in both the companies and genebanks receive annual training in seed multiplication and characterization. Information and regeneration experiences are shared among members in yearly workshops. NBPGR India collaborates with institutions affiliated to the Indian Council of Agricultural Research to regenerate their eggplant accessions.

Strengthen the AARNET collaboration to safeguard diversity collected in Southeast Asia

A large-scale programme to collect vegetable germplasm from Southeast Asia was initiated in the 1990s (Engle and Faustino, 2007). The project was funded by the Asian Development Bank and was a collaboration among WorldVeg and nine countries from Southeast Asia. Eggplants were among the target species. WorldVeg is currently regenerating these accessions. Continued collaboration with national genebanks across the entire Southeast Asia region could benefit all the stakeholders. The national genebanks of all ASEAN countries should establish collaborations at the regional level to facilitate the open exchange of germplasm across regions.

Collaboration to regenerate CWR

Eggplant is one of the species included in the Crop Wild Relative Project, coordinated by the Crop Trust. Missions to collect eggplant resources were conducted between 2013 and 2019 in several countries, but further collecting missions are recommended (Müller et al., 2021). The coordinated regeneration of this germplasm is ongoing. The CWR are of particular interest as they are often perennial and require specific environments. They are also more difficult to outsource to breeding companies or breeding programs. A collaboration on the regeneration of CWR has been established between RBG Kew and WorldVeg, and germplasm has been exchanged under SMTAs. Post-entry quarantine facilities have been established to introduce new germplasm into Taiwan, and to date 217 accessions have been shared for regeneration, phenotyping, and genotyping. Further collecting missions to fill collection gaps should be carried out in collaborations with national institutions (see Activity 1).

Regarding other issues to be addressed, the Solanaceae collection previously held at the Radboud University in the Netherlands, with more than 3000 accessions of wild origin, is currently maintained in freezers at the Centre for Genetic Resources, The Netherlands. These materials are no longer available for distribution and need curation. INRAE (France) also has a large collection of eggplant CWR in need of regeneration. Other collection holders may have similar backlogs. These are huge tasks and require collaboration and prioritization, as well as funding. Curation and regeneration of these collections should include gap analysis and duplicate screening, as noted previously.

Collaboration on safety backups

We recommend to continue to back-up collection in partnership with other collection holders or the Svalbard Global Seed Vault.

Fundraising

Several collection holders reported that identifying/obtaining sustainable funding for collections is a challenge. A shortage of resources is a key issue in conserving collections and making them available for use. Several curators highlighted backlogs in seed multiplication and safety duplication. A lack of resources in the form of staff or operating funds is an issue that could lead to the loss of eggplant accessions.

Projects that support safeguarding the collections, such as the BOLD project coordinated by the Crop Trust, should be continued or expanded.

4.6 Targeted collection missions

The review and the survey identified some gaps in the current eggplant collections. The strategy proposes to organize targeted collection missions to fill priority collection gaps that will be identified as described under section 4.3. Targeted collection missions should prioritize CWR species that have only a few accessions in the global conservation system. Among the CWR priority checklist species (Vincent et al., 2013) less than 50 accessions in the global conservation system are recorded for *Solanum linnaeanum*, *Solanum asperolanatum*, *Solanum cumingii*, *Solanum lidii*, *Solanum marginatum*, *Solanum rubetorum*, and *Solanum tomentosum*. The two IUCN red-listed species *Solanum rigidum* and *Solanum lidii* are among these. Landraces should still be collected, and especially in regions of domestication with a low coverage of accessions in the global conservation system. Africa has been identified as a priority region for further collecting (see section 2.7), but an additional thorough gap analysis should be conducted to map priority areas for collection missions.

4.7 Characterization for facilitating use

A well-characterized collection will be easier to use. Support for genotyping accessions across many genebanks will ultimately increase the use of the global eggplant collection. We recommend collection holders to collaborate on characterization projects. The data could be used in house to facilitate better information on traits and genetic information, but the data could also be used to facilitate a global core collection. Such a core collection should be built on genomic, geographic, and environmental data, and across different collection holders. A subset of candidate accessions should be characterized morphologically. More details are provided in the implementation plan.

4.8 Collaborative efforts for using CWR in breeding

Although breeding programs have successfully produced high-quality eggplant varieties and hybrids, there are continuing challenges in further improving the crop. The use of CWR in breeding is still limited. We should continue established collaborations among collection holders, as is the case for the ECPGR Solanaceae working group or the Horizon 2020's G2P-SOL project. Future collaborative efforts should include screening of the eggplant germplasm and its CWR for resistance to abiotic and biotic stress. This information, combined with genomic studies to detect important genes and QTLs of agronomic importance and their associated markers, will be of great value in eggplant breeding efforts, as has been demonstrated in association mapping studies (Cericola et al., 2014; Portis et al., 2015). Large-scale phenotyping and genotyping projects are also interesting as follow-ups to G2P-SOL.

Crosses between cultivated eggplant and its CWR are difficult due to sexual incompatibility. Another issue is the linkage drag caused by the associations between resistance genes and the many detrimental traits present in CWR (Frary et al., 2007). In addition, there is limited information on the genetic control of important traits and resistance to pests and diseases in CWR. Use of eggplant genetic resources and pre-breeding activities using landraces, open-pollinated cultivars, and CWR is a high priority for eggplant breeders. The goal is to develop introgression lines using species from GP1, GP2, and GP3 to broaden the genetic base of eggplant, and generate cultivars adapted to climate change (Daunay and Hazra, 2012; Rotino et al., 2014).

Here, we suggest two interrelated tasks:
1. Establish a public-private partnership for CWR screening for resistance traits; and
2. Establish a public-private partnership for pre-breeding with the use of CWRs.

Establishment of a public-private partnership for CWR screening for resistance traits

Screening eggplant germplasm for resistance is time consuming and costly. There are studies described that have done germplasm characterization to identify sources of tolerance to abiotic stresses such as drought, salinity or extreme temperatures (e.g. García-Fortea et al., 2019; Taher et al; 2019). Further screening of genebank holdings could provide new information about germplasm accessions resistant to specific strains and other pests and diseases. Priority diseases are bacterial wilt, Fusarium wilt, and Verticillium wilt. Priority pests are eggplant fruit and shoot borer, whitefly and two-spotted spider mite. The first task could be to establish a consortium for a public-private partnership project with external funding. This needs an initiative and a coordinated team. The consortium would be responsible for applying for external project funds. The public-private evaluation project "European Evaluation Network" (EVA), set up by ECPGR, is a good example.

Establish a public-private partnership for pre-breeding using CWRs

Pre-breeding that includes CWR is a costly and time-consuming process that most breeding enterprises do not undertake. To make progress in this area, we recommend to establish a consortium for a public-private partnership project with members from breeding enterprises, genebanks, universities and research institutions, supported by external funding. The concrete tasks of the prebreeding work could include the development of introgression lines with CWRs. for adaptation to climate change and pests- and disease resistance.

4.9 Implementation, governance, and funding

This strategy highlights the need for coordination and collaboration. An international organization like the WorldVeg could play key roles in the implementation and governance of this eggplant strategy. In addi-

Table 4.2. Tentative budget for implementing the global strategy for the conservation and use of eggplant genetic resources (in EUR). In-kind contribution comes in addition.

Activity and items	Year 1	Year 2	Year 3	Year 4	Total
Establishment of a global eggplant working group and knowledge platform, and attraction of funds for a global eggplant collection (Activity 1)	50,000	25,000	25,000	25,000	125,000
Data uploading, gap analysis and duplicate screening (Activity 2)	20,000	20,000	20,000	20,000	80,000
Plant health issues (Activity 3)	35,000	35,000	35,000	35,000	120,000
Regeneration and safety duplication (Activity 4)	187,500	1875,00	187,500	187,500	750,000
Morphological and molecular characterization of accessions (Activity 5)	50,000	50,000	50,000	50,000	200,000
Targeted collection missions to fill collection gaps (Activity 6)		75,000	75,000		
Use of CWR in breeding, consultation with users to identify important traits (resistance, quality, nutrition) and establishment of public-private partnerships (Activity 7)	40,000	40,000	20,000	20,000	120,000
Total	**327,500**	**402,500**	**382,500**	**307,500**	**1,420,000**

tion, the involvement of national collection holders and research institutes is fundamental for the success of the strategy plan. A coordinated approach would strengthen the likelihood of success. Much knowledge can be gained through cooperative efforts that include the sharing/exchange of expertise, capacity building and life-long learning.

We recognize that funding is needed for the proposed activities. Targeted funds are also needed to reduce backlogs in regeneration and backing-up of materials, especially CWR and landraces.

In this document, we present a 4-year implementation plan. We suggest the following key activities with approximate budget figures for each one (Table 4.2). These are, however, only approximations based on the best current knowledge. The actual figures need to be revised after verification and discussion. We recognize that external project funds are needed to scale-up activities and implement changes. This is especially the case for screening and pre-breeding activities. In-kind contributions and stakeholder engagement will also be essential for implementation of the strategy.

Global eggplant working group and knowledge platform (Activity 1)

The timeframe for organizing the working group is one year. This group will work towards establishing a global eggplant collection. We acknowledge that a functional network requires a continuous and coordinated effort.

We suggest an EKP website with information targeted to eggplants and that includes management protocols for regeneration, keys for identification of wild species, and protocols for seed treatments and pathogen identification and control.

To coordinate the development of the global eggplant collection, we suggest a 4-year budget of EUR 125,000.

Coordination: [Consultant or collection holder] in collaboration with WorldVeg.

Gap analysis and duplicate screening (Activity 2)

The timeframe to update data in Genesys is 2 years. For gap analysis and duplicate screening, the timeframe to initiate the activity is 4 years. To fully complete this activity, more time will be needed depending on the budget and the level of involvement of the various collection holders.

We suggest a coordinated activity that includes as many collection holders as possible, but where an individual consultant or one collection holder is responsible for coordination. We recommend to give priority to collection holders that today are not represented with data in Genesys. This will be in close collaboration with the Crop Trust, which manages Genesys. The highest priority is to upload and update passport data to ensure its completeness. Uploading of C&E data could be included in this activity.

This work will mainly be done as in-kind contributions of the various collection holders, but project funds for a coordinator to facilitate the process would help in scaling. A realistic amount is EUR 80,000 for the coordination work, in addition to the in-kind contributions from the collection holders and Genesys.

Coordination: [Consultant or collection holder] in collaboration with Genesys and the Crop Trust.

Plant health issues (Activity 3)

The timeframe for this activity is 4 years.

Sharing knowledge and experience in collection management and seed-cleaning techniques is a high priority. Appropriate treatments will avoid the occurrence and inadvertent distribution of seed-borne diseases like viruses and viroids. Collaborations would include sharing of protocols and experience, and applications for external research project funds to acquire new knowledge. Capacity building and training of curators should be a priority, as well as compiling protocols and SOPs. The development and use of new technologies for pathogen identification and elimination are also encouraged.

In-kind contributions from the collection holders with the broadest experience would cover the main costs of this activity. However, EUR 100,000 is a realistic estimate for coordination, capacity building and training.

Coordination: [Consultant or one collection holder] in collaboration with Activity 1.

Regeneration and safety duplication (Activity 4)

The timeframe for this activity is 4 years.

Several collection holders have backlogs in regeneration and safety duplication. The CWR are of particular interest, as they often are perennial and require specific environments for growth and seed production. Backlogs in the regeneration and safety duplication of landraces are also a concern that requires collaborative action.

We suggest a plan to coordinate collaborations among collection holders and provide support to regenerate/duplicate priority germplasm. A priority list of around

3,000 CWR and landrace accessions in need of regeneration and support will be assembled by the global eggplant working group.

In-kind contributions from the collection holders would cover the main costs of this activity. However, EUR 750,000 (3000 accessions, at 250 EUR/accession) should be sufficient to begin work to reduce the backlog in current regeneration/duplication of eggplant CWR and landraces. The majority of the resources will be transferred to targeted genebanks to support regeneration work. For additional regeneration activities, collaborations will be sought with the seed industry.

Collection missions (Activity 5)

Although the strategy emphasizes the regeneration of existing backlogs, it also proposes two to four targeted missions to collect 500 accessions to fill collection gaps, as defined in Activity 2. The locations should be defined after a thorough gap analysis but priority should be given to landraces from centers of domestication (South and East Asia) and Africa, and CWR with few accessions conserved. These are mostly species from Africa.

Morphological and genomic characterizations (Activity 6)

To increase the use of the global eggplant collection, the strategy aims to improve understanding of the collection through a broad genotyping, including around 10,000 accessions across as many genebanks as possible and covering different countries of origin and environments of origin. From the genotyping a subset of candidates for a core collection will be specified. Further detailed morphological information can be added, including data pertaining to, and images of, fruits, flowers, and leaves. A global core collection of approx. 1000 accessions would be an appropriate suggestion.

The aim is to genotype about 10,000 accessions as a first step to build this core collection. This will include accessions of the three cultivated eggplants and its CWR in the first 2 years of the strategy (10,000 accessions × 10 Euro = 100,000 Euro). In years 3 and 4, the core collection of about 1,000 accessions will be morphologically characterized and systematically imaged (1,000 accessions × 100 Euro = 100,000 Euro).

Promote the use of CWR in breeding through public-private partnerships (Activity 7)

There is a need to clarify the demand for CWR in breeding, and to identify which breeding groups will undertake this work. To establish and implement public-private partnerships in screening and pre-breeding with the use of CWRs need time. To establish a consortium would be a first step, and a timeframe for this and an initial screening for biotic and abiotic stress tolerance of the first 100 CWR accessions is 4 years. These accessions should be selected by the consortium members but would likely be of CWR that is not too difficult to hybridize with eggplant. Further research depends on whether the consortium secures external funding. This work can build on previous studies that have identified resistant/tolerant CWR germplasm. Pre-breeding can be conducted using materials with known resistance traits. The global eggplant working group will assemble a priority list of potentially useful accessions to include in this work.

We suggest an implementation plan to coordinate collaborations among collection holders. In-kind contributions from the collection holders would cover the main costs for this activity but seeding money to coordinate and establish the consortium for starting the screening and prebreeding is necessary. We suggest EUR 120,000 for this seeding money over a 4-year period. Some of the resources will be transferred to targeted consortium members for doing the first screening/pre-breeding work.

Coordination: [consultant and collection holder].

Tentative budget for activities

A tentative budget for implementing the global strategy, based on estimated costs, is provided in Table 4.2. In-kind contributions are additional.

4.10 Conditions for success and indicators

With mutual trust and understanding established, a high level of impact can be achieved *via* collaborations. We believe that this will attract diverse funding sources (Pearce et al., 2020). There are many eggplant collections around the world, but only a few are extensive. Nevertheless, eggplant is an Annex I crop, which places it among many staple crops that are important in a global context. If eggplant is just another crop among a series of others, and there are few accessions, the crop will not be a high priority. This does not necessarily imply that the materials are threatened, but rather that the focus is not there. The situation is different for larger eggplant collections, because they have personnel dedicated to the management of the materials. The number of individuals with specific knowledge of eggplant conservation and use is limited. Therefore, networking, capacity building and coordination are important to increase the number of skilled workers.

The strategy relies on institutions to share their knowledge, data and goodwill. We believe that the approach described will strengthen collaborations and reduce knowledge gaps and backlogs, and will, therefore, contribute to the long-term conservation of eggplant diversity in all participating countries. This will also facilitate the use of the germplasm. We recommend a loose intention agreement to be signed by all parties contributing to the strategy and its implementation. This will ensure participation, data sharing and a willingness to contribute to collaborations across borders and continents. An international organization should be responsible for executing this work.

Important indicators for the first 4-year period are as follows:

- Establishment of a global eggplant working group (Activity 1).
- Establishment of an open-access EKP with a minimum of eight published guidelines/manuals/ articles, and completion of at least eight scientific webinars on eggplant conservation and use (Activity 1).
- Improvement of passport data accuracy and completeness for eggplant collections in Genesys, especially data on biological status, country of origin, and donor or collection site information (Activity 2).
- At least 10 eggplant C&E datasets uploaded to Genesys (Activity 2).
- Publication of a global gap analysis for cultivated eggplants and eggplant CWR (Activity 2).
- Protocols for reducing seed-borne diseases in eggplant are developed and included in SOPs for at least 10 collection holders (Activity 3)
- Capacity building to address plant health-related issues *via* training and guidance of a minimum of 10 curators responsible for eggplant materials (Activity 3).
- Development of a priority list for regeneration of CWR and landraces, and the regeneration and duplication of at least 2000 eggplant accessions with support from the global eggplant working group (Activity 4).
- Establishment of collaborative efforts that include the participation of the breeding industry to regenerate eggplant accessions in at least 10 collections (Activity 4).
- Completion of genotyping of about 10,000 accessions of the three cultivated eggplants and their CWR, and morphological characterization and imaging of about 1000 accessions (Activity 5).
- Collection gaps identified and prioritized for targeted collections (Activity 6).
- Collection missions executed and at least 500 new accessions of targeted CWR and landraces collected (Activity 6)
- Biotic and/or abiotic stress tolerance screening of a minimum of 100 CWR accessions conducted by selected collection holders with support from the global eggplant working group (Activity 7).
- Establishment of a public-private partnership consortium and submission of two applications for large-scale screening and pre-breeding of CWR (Activity 7).

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6 APPENDIXES

Appendix 1. Participants in the consultations

Banque Nationale de Gènes	Tunisia	Najla Mezghani
Institute of Vegetable and Melon Growing of NAAS	Ukraine	Roman Krutko
World Vegetable Center	Taiwan	Maarten van Zonneveld
ICAR-National Bureau of Plant Genetic Resources	India	Chithra Devi Pandey
The National Institute of Horticultural Research	Poland	Mariusz Chojnowski
Agroscope	Switzerland	Beate Schierscher
CSIR-Plant Genetic Resources Research Institute	Ghana	Yaw Kwateng
Institute of Biosciences and BioResources (National Research Council)	Italy	Gaetano Laghetti
Department of Agricultural Research (DAR)	Myanmar	Htwe Min Thant
DOA Genebank	Thailand	Kunyaporn Pipithsangchan
INRAE Centre for Vegetable Germplasm	France	Rebecca Stevens
Faculty of Agricultural Sciences and Food, Skopje	North Macedonia	Sonja Ivanovska
Leibniz Institute of Plant Genetics and Crop Plant Research (IPK)	Germany	Ulrike Lohwasser
Centre for Genetic Resources, The Netherlands (CGN)	The Netherlands	W. van Dooijeweert
Kafrelsheikh University	Egypt	Mohamed Radka

Appendix 2. Selected metrics for eggplant and tomato (as comparison)

Below is a summary of information on crop conservation strategies from the Crop Trust's report, "The plants that feed the world: baseline data and indicators for PGRFA." The report presents the findings of a study to specify baselines and a set of indicators for around 350 plants contributing to global food security and sustainable agriculture. This study was a collaboration between CIAT, the Plant Treaty Secretariat and the Crop Trust, funded by NORAD via the Plant Treaty. The summary in this annex was written by Dr. Felix Frey, International Consultant, Global Crop Diversity Trust.

Khoury et al. (2022) compiled a comprehensive dataset as part of a project funded by the International Treaty on Plant Genetic Resources for Food and Agriculture and the Crop Trust, led by the International Center for Tropical Agriculture (CIAT). The aim was to introduce five normalized reproducible indicators that provide an evidence base to prioritize actions with respect to the conservation and use of crop genetic resources for food and agriculture. The indicators include metrics associated with the USE of a crop (global importance), the INTERDEPENDENCE between countries with respect to genetic resources, the DEMAND of researchers for genetic resources, the SUPPLY of germplasm by gene banks and the SECURITY of germplasm conservation. The indicator results are publicly available on an interactive online website. To generate the five indicators, Khoury et al., 2022 collected a comprehensive dataset from multiple sources. Below, we do not present the indicators created by Khoury et al. (2022), but we discuss the underlying raw data to shed light on the different aspects represented by the indicators.

To put some numbers into context, we compare eggplant with tomato. Both crops are comparable with respect to the type of propagation and use (both are botanical fruits used vegetables), and both are in the genus *Solanum.* Tomatoes are represented by the species *Solanum lycopersicum*. Eggplant is represented by the species *Solanum melongena.* Another closely related eggplant species, from the same subgenus as eggplant (*Leptostemonum*) is the African eggplant *Solanum aethiopicum*, originating from West Africa. Because data for the latter crop is scarce and its importance is low compared with eggplant, we have included it in the overview table (Table 1), but we do not discuss it further here. Hereafter, we refer to eggplant as *S. melongena*.

The metrics for "Global production", "Food supply" and "Quantity exported globally" from the indicator domain "Crop use" are annual average values drawn from FAOSTAT data from 2010 to 2014. The percentage of countries producing and consuming (being supplied with) the crop is calculated as the number of countries where that crop is within the top 95% of most important crops divided by the number of countries reporting numbers for that crop (this can differ among metrics and crops). The global production of eggplant is at about 46 million tons annually, which is 29% of global tomato production (160 million tons). The quantity of food supplied by eggplant, i.e. the average global consumption, is about 20 g/person/day, while that of tomato is 55 g/person/day. In this respect, data for eggplant has to be read with caution, as food supply for this crop is not directly reported by FAOSTAT. Instead, it is included with other vegetables in the category "vegetables, other". Khoury et al., 2022 inferred the numbers for food supply from eggplant from the total food supply of "vegetables, other", considering total global production shares of all the vegetables within the category. Eggplant is produced around the world, with 42% of countries producing significant amounts. For comparison, tomato production occurs in 81% of countries. Although tomato and eggplant are both internationally important vegetables, the export shares are only 1% and 8% of total eggplant and tomato production, respectively (439 thousand tons and 12 million tons). Thus, their use is relatively high in their producing countries. According to the numbers calculated by Khoury et al. (2022), all countries world-wide consume eggplant, while 98% of countries world-wide consume tomatoes. We suspect that the number of countries consuming eggplant is actually lower, because the data were inferred from numbers for "vegetables, other", as mentioned above.

The crop use metrics with respect to research were assessed by manual searches on Google Scholar. Searches were conducted for the respective genus or species in the titles of publications, including patents and citations, between the years of 2009 and 2019 (Khoury et al., 2022). The number of hits in Google Scholar is indicative of the level of scientific interest in a crop. The *Solanum* genus, which includes eggplant, potato, tomato, and other crops was present in 16,500 publication titles. The eggplant species *S. melongena* had 2,630 hits Google Scholar, a little more than half of the number for *S. lycopersicum* (tomato, 4,740 publications). Considering that the production of eggplant is only 29% of that of tomato, eggplant research is overrepresented when compared with tomato research.

Khoury et al. (2022) defined interdependence as a measure of the degree of dependence of the global cultivation and use of a certain crop on the germplasm present at the primary centers of diversity of that crop. Primary centers of diversity are not represented by countries, but by 23 agroecological zones (Khoury et al., 2016). This is because crop diversity does not follow national borders but rather climatic and agroecological boundaries. Interdependence is high in crops that originate from a small area and are cultivated and used globally. For production, interdependence is calculated by dividing a crops' production outside of the primary center of diversity by the global production. If all production is outside the primary center of diversity, interdependence is 100%. For food supply, interdependence is calculated by dividing the food supply by the world average. Food supply outside can be higher than that inside the primary regions of diversity, and thus, will be higher than the global mean. Therefore, interdependence with respect to food supply can be above 100%. Interdependence with respect to production is much lower for eggplant (10%) than for tomato (98%). This is because main production areas of eggplant are in regions inside of primary centers of diversity (South and South East Asia), foremost China and India, whereas almost all tomato production is outside its primary centers of diversity in Central and Andean South America. Compared with the interdependence of production, the interdependence of food supply for eggplant is higher (44%). This is because eggplant consumption is more widely distributed throughout the world than is eggplant production. As discussed before, these values have to be treated with caution, as the food supply of eggplant was calculated indirectly.

The demand for germplasm is defined by two metrics (Khoury et al., 2022). First, by the number of distributions of accessions by genebanks, as an annual average between 2014 and 2017 based on data from the Plant Treaty Information System. Second, by the number of varieties released during the 5 years between 2014 and 2018, obtained from the International Union for the Protection of New Varieties of Plants (UPOV). There is an extremely high use of eggplant germplasm, as reflected by the 11,098 eggplant accessions that are requested from genebanks each year. This is similar to the number of requests for tomato accessions (10,967). However, the number of new eggplant cultivars is relatively low. During a 5-year period, 2,124 varieties of eggplants were released, compared with 30,367 varieties of tomato during the same period.

Khoury et al. (2022) illustrated the supply of germplasm using the number of accessions available in *ex situ* collections around the world, with respect to the crop genus and the most important species of that crop. Khoury et al. (2021) also assessed the number of accessions (again with respect to genus and species) that were available under the multilateral system (MLS) of the Plant Treaty. This was done first, directly, as notation (in MLS/not in MLS) in the public online databases Genesys, WIEWS and GBIF. Secondly, the availability of accessions was assessed *via* the status of the country where the institution holding the respective germplasm collection was located. If the country was contracting partner of the Plant Treaty, the respective accession was regarded as available *via* the MLS. According to databases, global *ex situ* collections hold a total of 122,252 *Solanum* accessions. Global eggplant collections holding 13,984 accessions are only 36% of the size of global tomato collections (39,305 accessions). Approximately one-fifth (21% and 22%) of eggplant and tomato accessions are available through the MLS, as noted in databases. However, because eggplant is listed in Annex I of the Plant Treaty, 74% of eggplant accessions are available indirectly under the MLS to institutes in countries with party status. In contrast, tomato is not listed in Annex I of the Plant Treaty, and therefore, no tomato accessions are indirectly available through a country's party status.

The security of germplasm conservation is represented here with two metrics, the safety duplication status at the Svalbard Global Seed Vault (SGSV), and the equality of global distribution with respect to several crop use metrics. The number of accessions safety duplicated with respect to genus and species were drawn from the website of the SGSV and were divided by the total number of accessions stored in global *ex situ* collections (see paragraph above), giving the percentage of safety duplicated germplasm. To represent the equality of distribution across different agroecological regions of the world (Khoury et al., 2016), Khoury et al. (2022) used the reciprocal 1-Gini index with respect to the different crop use metrics. The Gini index is the most commonly used inequality index (Gini index, 2008), and has mainly been used to quantify global income inequality. The 1-Gini index, presented here, ranges from 0 to 1, where 0 reflects very unequal distribution across world regions and 1 represents a completely equal global distribution. It reflects the security of crop cultivation and use. Small indices of production and thus, geographical restriction, go hand-in-hand with a higher vulnerability of supply, for example, in cases of natural disasters. A relatively high number of eggplant accessions are safety duplicated at the SGSV (60%), compared with 34% of tomato accessions and 14% of all global *Solanum* accessions.

Equality of distribution with respect to global production is very low for eggplant (0.01) and for tomato (0.04). This is because of the more restricted area of

Table 1. Selected metrics collected by Khoury et al., 2022 for eggplant and tomato, subdivided by indicator domain

Metric	Eggplant	Tomatoes	Eggplant / Tomato	African egg-plant
Crop use				
Global production [tons]	46,228,050	160,252,190	29%	NA
Food supply (Amount consumed) [g/capita/day]	20	55	35%	NA
Percentage of countries producing crop *	42%	81%	52%	NA
Percentage of countries consuming (being supplied with) crop *	100%	98%	102%	NA
Quantity exported globally [t]	439,109	12,048,216	4%	NA
Number of publications between 2009-2019, including patents and citations, searching title of publication (Google scholar search hits) for genus **	16,500	16,500	100%	16,500
Number of publications between 2009-2019, including patents and citations, searching title of publication (Google scholar search hits) for species ***	2,630	4,740	55%	125
Interdependence				
Interdependence of global production from germplasm from primary centers of diversity [0-1] ****	10%	98%	10%	NA
Interdependence of global food supply from germplasm from primary centers of diversity [0-1] ****	44%	102%	43%	NA
Demand				
Accessions distributed from genebanks (Annual average 2014-2017)	11,098	10,967	101%	10,618
Variety releases in 5 years (2014-2018)	2,124	30,367	7%	2
Supply				
Number of accessions in *ex situ* collections of genus **	122,252	122,252	100%	122,252
Number of accessions in *ex situ* collections of species ***	13,984	39,305	36%	1,388
Accessions of the genus ** available through Multilateral System (MLS) directly noted in databases [%]	32%	32%		32%
Accessions of the species *** available through Multilateral System (MLS) directly noted in databases [%]	21%	22%		41%
Accessions of the genus ** available through Multilateral System (MLS) indirectly by matching institute countries with party status [%]	84%	0%		0%
Accessions of the species *** available through Multilateral System (MLS) indirectly by matching institute countries with party status [%]	74%	0%		0%
Security				
Accessions of genus ** safety duplicated in Svalbard Global Seed Vault [%]	14%	14%		14%
Accessions of species *** safety duplicated in Svalbard Global Seed Vault [%]	60%	34%		94%
1-GINI index for equality of production across the world [0-1] *****	0.01	0.04	27%	NA
1-GINI index for equality of food supply across the world [0-1] *****	0.26	0.19	135%	NA

* Counting countries listing the crop within the top 95% (FAOSTAT); Calculated as: Number of countries counting crop (top 95%)/total number of countries (production 216, food supply 175)
** Eggplant and tomato (and African eggplant): *Solanum*
*** Eggplant: *Solanum melongena*; Tomatoes: *Solanum lycopersicum* (African eggplant: *Solanum aethiopicum*)
**** Global metric / Metric at primary center of diversity
***** Relative equality of crop use across world regions (same regions as used in interdependence domain), high equality give high indicator value

production, as stated above, and large countries like China and India accounting for the bulk of eggplant production. The quality of the distribution of food supply across different regions of the world is higher for eggplant (0.26) than for tomato (0.19). The higher equality of distribution of food supply of eggplant could be distorted, because the eggplant food supply was calculated from data for "vegetables, other", as mentioned above.

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Appendix 3. Survey questions

Survey respondent name	Open-Ended Response
Survey respondent email address	Open-Ended Response
Survey respondent relationship to the collection	Open-Ended Response
Name of organization with eggplant collection	Open-Ended Response
Organization address and country	Open-Ended Response
Website	Open-Ended Response
Curator/researcher responsible for the collection	Name and address
Is the organization holding the eggplant collection:	Response; Name and address of larger organization:
Type of organization	Government; Public-funded university; Private, Non-governmental organization (NGO)/Nonprofit; Individual; Other (please specify)
Is this organization the legal owner of the collection?	Response
Is this collection subject to the International Treaty on Plant Genetic Resources for Food and Agriculture?	Response; Comments. If not, is there an anticipated date of entry into the ITPRGFA?
Who is financing the conservation of the collection and to what extent?	Government (%); Private sector (%); International/regional organization/agency (%); Other funding agencies (%) please specify
What are the primary conservation priorities of the collection (check all that apply)?	Internationally important cultivars; Local cultivars; Wild materials; Breeding materials; Other (please specify)
Are you a member of an international eggplant network or research projects?	Response Please specify:
Number of accessions of cultivars (including old ones) of Brinjal eggplant (*S. melongena*):	
Number of accessions of local cultivars/landraces of Brinjal eggplant (*S. melongena*):	
Number of accessions of breeding materials of Brinjal eggplant (*S. melongena*):	
Number of accessions of wild origin and of species in the primary genepool for Brinjal eggplant (*S. melongena* and *S. insanum*):	
Number of accessions of wild origin and of species in the secondary or tertiary genepool for Brinjal eggplant (*S. campylacanthum, S. incanum, S. lichtensteinii, S. linnaeanum, S. lidii, S. vespertilio, S. violaceum, S. tomentosum, S. pyracanthos, S. torvum, S. sisymbriifolium, S. elaeagnifolium, S. virginianum, S. grandifolium*, or others):	
Number of accessions of cultivars (including old ones) of scarlet eggplant (*S. aethiopicum*) and gboma eggplant (*S. macrocarpon*):	
Number of accessions of local cultivars/landraces of scarlet eggplant (*S. aethiopicum*) and gboma eggplant (*S. macrocarpon*):	
Number of accessions of breeding materials of scarlet eggplant (*S. aethiopicum*) and gboma eggplant (*S. macrocarpon*):	
Number of accessions of wild origin of scarlet eggplant (*S. aethiopicum*) and gboma eggplant (*S. macrocarpon*):	
Total number of eggplant accessions in collection (including all above categories):	
What are the known collection gaps?	Open-Ended Response
If any gaps are identified; is there a timeframe for filling them?	Open-Ended Response
Are there efforts to conserve them in situ or ex situ? Describe	Open-Ended Response
Do you have wild eggplant native to your country? Which species? and are they included in your collection?	Open-Ended Response
To what extent are pests or diseases having an effect on the collection?	Causing annual losses of accessions; Preventing distribution; Comments
What pathogens and diseases threaten the collection?	Open-Ended Response
What pathogens are tested for in the collection?	Open-Ended Response
What are the phytosanitary/quarantine requirements for receiving new materials?	Open-Ended Response
What percentage of the accessions are pathogen tested?	Open-Ended Response
What percentage of the accessions are "cleaned-up"?	Open-Ended Response
How many plants are used per accession for regeneration/seed multiplication?	Response Other (please specify)
What measures are taken for isolation during regeneration/seed multiplication?	Response Other (please specify)
What are the seed storage conditions for the long-term storage?	Temperature; Humidity; Packing material

How is the viability monitoring carried out?	Initial viability monitoring practiced? Periodic viability monitoring? How frequent? How many seeds are used in one germination test?
Describe the back-up status of the collection (type of back-up: secondary collection elsewhere, and percentage of accessions backed-up):	Open-Ended Response
What are the barriers to collection back-up?	Open-Ended Response
On average, how many eggplant accessions are distributed per year?	Open-Ended Response
On average, how many unique recipients receive eggplant material per year?	Open-Ended Response
Are your materials distributed:	To researchers?; To breeding programs?; To industry?; To the public?; Other (please specify)
Are there limitations on material use? If so, what are they?	Open-Ended Response
What are the distribution costs to the recipient?	Open-Ended Response
What types of agreements/permits are necessary for distribution?	Open-Ended Response
Percent distribution to domestic recipients	Open-Ended Response
Percent distribution to foreign recipients	Open-Ended Response
Other comments regarding acquisition and distribution:	Open-Ended Response
Are standardized methods used for phenotypic evaluations for the collection? Which ones? Please provide references.	Open-Ended Response
Are standardized methods used for genotypic characterization of the collection? Which ones? Please provide references.	Open-Ended Response
What is the name of the database used for documenting the collection?	Open-Ended Response
What is the website URL for the database (if public)?	Open-Ended Response
What language(s) is the website interface for the database?	Open-Ended Response
The information/database is:	Response Other (please specify)
Information is available for:	Passport: - Public; Internal; Available by contacting the curator Taxonomy: - Public; Internal; Available by contacting the curator Images: - Public; Internal; Available by contacting the curator Phenotypes: - Public; Internal; available by contacting the curator Genotypes: - Public; Internal; available by contacting the curator Pathogen status – Public; Internal; Available by contacting the curator Other (please specify)
Are there key publications (peer reviewed, popular press, online, etc.) about the eggplant collection? Please provide links/citations.	Open-Ended Response
Internal use within your organization:	Plant and/or pathogen research; Molecular characterization Phenotypic evaluation; Pre-breeding; Breeding; Genomics Propagation for resale; Other (please specify)
Use of distributed materials	Plant and/or pathogen research; Molecular characterization; Phenotypic evaluation; Pre-breeding; Breeding; Genomics; Propagation for resale; Certification programs; Other (please specify)
Is there a person with specific knowledge dedicated to eggplant conservation/curation of the collection?	Response Other (please specify)
If YES on the above, how much time is this person(s) dedicated for eggplants?	Response Other (please specify)
What type of constraints (if any) do you face affecting the conservation of eggplants?	Staff numbers (explain); Staff training (explain); Capacity to replant/maintain the collection (explain); Budget (explain); Other (explain)
Will some of the above constraints result in a loss of germplasm?	Open-Ended Response
Please describe the major needs or concerns influencing the long-term sustainability of the collection	Open-Ended Response
What changes to the present situation would you consider to be essential for the long-term conservation of eggplant at a global level?	Open-Ended Response

Appendix 4. Global priority crop wild relative list

Global priority crop wild relative (CWR) list with numbers of ex situ *collections (data sourced from GBIF), arranged by crop (after Vincent et al., 2013).*

Solanum melongena – Aubergine – Gene Pool Concept					
Solanum aculeatissimum Jacq.	55	*Solanum anguivi* Lam.	75	*Solanum anomalum* Thonn.	0
Solanum asperolanatum Ruiz & Pav.	0	*Solanum campylacanthum* Hochst. ex A. Rich.	0	*Solanum cumingii* Dunal	2
Solanum grandiflorum Ruiz & Pav.	0	*Solanum incanum* L.	39	*Solanum insanum* L.	0
Solanum lidii Sunding	3	*Solanum linnaeanum* Hepper & P.M. L. Jaeger	10	*Solanum macrocarpon* L.	100
Solanum marginatum L. f.	2	*Solanum rubetorum* Dunal	0	*Solanum sisymbriifolium* Lam.	17
Solanum tomentosum L.	2	*Solanum torvum* Sw.	178	*Solanum violaceum* Ortega	0

Appendix 5. Standardization of taxa in the eggplant genepool

Taxon found in Genesys or WIEWS	Standardized taxon
Solanum aethiopicum	*Solanum aethiopicum* L.
Solanum aethiopicum aculeatum group	*Solanum aethiopicum* L.
Solanum aethiopicum gilo group	*Solanum aethiopicum* L.
Solanum aethiopicum group aculeatum	*Solanum aethiopicum* L.
Solanum aethiopicum group gilo	*Solanum aethiopicum* L.
Solanum aethiopicum group kumba	*Solanum aethiopicum* L.
Solanum aethiopicum kumba group	*Solanum aethiopicum* L.
Solanum aethiopicum shum group	*Solanum aethiopicum* L.
Solanum gilo	*Solanum aethiopicum* L.
Solanum integrifolium	*Solanum aethiopicum* L.
Solanum agnewiorum	*Solanum agnewiorum* Voronts.
Solanum adoense	*Solanum anguivi* Lam.
Solanum aldabrense	*Solanum anguivi* Lam.
Solanum anguivi	*Solanum anguivi* Lam.
Solanum indicum	*Solanum anguivi* Lam.
Solanum sodomeum	*Solanum anguivi* Lam.
Solanum anomalum	*Solanum anomalum* Thonn.
Solanum asperolanatum	*Solanum asperolanatum* Ruiz & Pav.
Solanum hispidum	*Solanum asperolanatum* Ruiz & Pav.
Solanum chrysotrichum	*Solanum aureitomentosum* Bitter
Solanum aureitomentosum Bitter	*Solanum aureitomentosum* Bitter
Solanum burchellii Dunal	*Solanum burchellii* Dunal
Solanum campylacanthum	*Solanum campylacanthum* Hochst. ex A. Rich.
Solanum panduriforme	*Solanum campylacanthum* Hochst. ex A. Rich.
Solanum capense	*Solanum capense* L.
Solanum catombelense	*Solanum catombelense* Peyr.

Taxon found in Genesys or WIEWS	Standardized taxon
Solanum cerasiferum	*Solanum cerasiferum* Dunal
Solanum cinereum	*Solanum cinereum* R. Br.
Solanum coagulans	*Solanum coagulans* Forssk.
Solanum dubium	*Solanum coagulans* Forssk.
Solanum cyaneopurpureum	*Solanum cyaneopurpureum* De Wild.
Solanum dasyphyllum	*Solanum dasyphyllum* Schumach.
Solanum macrocarpon var. *sapinii*	*Solanum dasyphyllum* Schumach.
Solanum deflexicarpum C.Y. Wu & S.C. Huang	*Solanum deflexicarpum* C.Y. Wu & S.C. Huang
Solanum forskalii Dunal	*Solanum forskalii* Dunal
Solanum bahamense	*Solanum glabratum* Dunal
Solanum glabratum Dunal	*Solanum glabratum* Dunal
Solanum goetzei	*Solanum goetzei* Dammer
Solanum acanthodes	*Solanum grandiflorum* Ruiz & Pav.
Solanum grandiflorum	*Solanum grandiflorum* Ruiz & Pav.
Solanum hastifolium	*Solanum hastifolium* Hochst. ex Dunal
Solanum hovei Dunal	*Solanum hovei* Dunal
Solanum humile	*Solanum humile* Lam.
Solanum rigescentoides	*Solanum humile* Lam.
Solanum inaequiradians Werderm.	*Solanum inaequiradians* Werderm.
Solanum incanum	*Solanum incanum* L.
Solanum incanum group a	*Solanum incanum* L.
Solanum insanum	*Solanum insanum* L.
Solanum lamprocarpum Bitter	*Solanum lamprocarpum* Bitter
Solanum lichtensteinii	*Solanum lichtensteinii* Willd.
Solanum lidii	*Solanum lidii* Sunding
Solanum linnaeanum	*Solanum linnaeanum* Hepper & P.-M. L. Jaeger
Solanum linnaeanum var. *schlechteri*	*Solanum linnaeanum* Hepper & P.-M. L. Jaeger
Solanum litoraneum A.E. Gonç.	*Solanum litoraneum* A.E. Gonç.
Solanum macracanthum	*Solanum macracanthum* A. Rich.
Solanum macrocarpom	*Solanum macrocarpon* L.
Solanum macrocarpon	*Solanum macrocarpon* L.
Solanum malindiense	*Solanum malindiense* Voronts.
Solanum marginatum	*Solanum marginatum* L. f.
Solanum mauense	*Solanum mauense* Bitter
Solanum melanospermum F. Muell.	*Solanum melanospermum* F. Muell.
Solanum melongena	*Solanum melongena* L.
Solanum melongena L.	*Solanum melongena* L.
Solanum melongena L.	*Solanum melongena* L.
Solanum melongena occidentale	*Solanum melongena* L.
Solanum melongena orientale	*Solanum melongena* L.
Solanum melongena subsp. *ovigerum*	*Solanum melongena* L.
Solanum melongena var *depressum*	*Solanum melongena* L.
Solanum melongena var *esculentum*	*Solanum melongena* L.
Solanum melongena var *serpentinum*	*Solanum melongena* L.

Taxon found in Genesys or WIEWS	Standardized taxon
Solanum melongena var. *graecum*	*Solanum melongena* L.
Solanum melongena var. *insanum*	*Solanum melongena* L.
Solanum melongena var. *ovigerum*	*Solanum melongena* L.
Solanum melonjena	*Solanum melongena* L.
Solanum ovigerum	*Solanum melongena* L.
Solanum nigriviolaceum	*Solanum nigriviolaceum* Bitter
Solanum polhillii Voronts.	*Solanum polhillii* Voronts.
Solanum platacanthum Dunal	*Solanum platacanthum* Dunal
Solanum richardii	*Solanum richardii* Dunal
Solanum rigidum Lam.	*Solanum rigidum* Lam.
Solanum rubetorum	*Solanum rubetorum* Dunal
Solanum ruvu Voronts.	*Solanum ruvu* Voronts.
Solanum setaceum	*Solanum setaceum* Dammer
Solanum sisimbrifolium	*Solanum sisymbriifolium* Lam.
Solanum sisymbrifolium	*Solanum sisymbriifolium* Lam.
Solanum sisymbriifolium	*Solanum sisymbriifolium* Lam.
Solanum sodomeodes Kuntze	*Solanum sodomeodes* Kuntze
Solanum stipitatostellatum Dammer	*Solanum stipitatostellatum* Dammer
Solanum supinum	*Solanum supinum* Dunal
Solanum taitense Vatke	*Solanum taitense* Vatke
Solanum tomentosum	*Solanum tomentosum* L.
Solanum torreanum	*Solanum torreanum* A.E. Gonß.
Solanum torvum	*Solanum torvum* Sw.
Solanum tovum	*Solanum torvum* Sw.
Solanum umtuma Voronts.	*Solanum umtuma* Voronts.
Solanum usambarense	*Solanum usambarense* Bitter & Dammer
Solanum usaramense Dammer	*Solanum usaramense* Dammer
Solanum vespertilio	*Solanum vespertilio* Aiton
Solanum viarum	*Solanum viarum* Dunal
Solanum vicinum	*Solanum vicinum* A.R. Bean
Solanum violaceum	*Solanum violaceum* Ortega
Solanum surattense	*Solanum virginianum* L.
Solanum virginianum	*Solanum virginianum* L.
Solanum xanthocarpum	*Solanum virginianum* L.
Solanum zanzibarense Vatke	*Solanum zanzibarense* Vatke

CROP TRUST

GENERAL CONTACT
+49 (0) 228 85427 122
info@croptrust.org

THE CROP TRUST
Platz Der Vereinten Nationen 7
53113 Bonn, Germany

MEDIA CONTACT
+49 (0) 228 85427 141
media@croptrust.org