GLOBAL STRATEGY FOR THE CONSERVATION OF *BRASSICA* GENETIC RESOURCES

With support from

CROP TRUST

The International Treaty ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Federal Ministry of Food and Agriculture

COVER

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DISCLAIMER

This document aims to provide a framework for the efficient and effective conservation of genetic resources of *Brassica* crops. The Crop Trust supported this initiative and commissioned the Warwick Genetic Resources Unit of Warwick University to coordinate the development of the strategy. The overall objective is to outline shared responsibilities and needs for the long-term conservation of these genetic resources and to facilitate their use for food security and sustainable agriculture. 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 February 2023) is expected to continue to evolve and be updated as and when circumstances change or new information becomes available.

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Cruciferae.

Brassica nigra Koch.

W. Müller.

Brassica nigra Kohler's Medizinal-Pflanzen

EXECUTIVE SUMMARY

Background to the strategy

The Global Crop Diversity Trust (the Crop Trust) is leading an initiative to develop global conservation strategies for key crops to support and prioritize key activities underpinning the effective conservation of crop diversity. This strategy document focuses on the six major crop species in the *Brassica* genus, a group of global agricultural, economic and nutritional significance. The document provides background information on the production and cultivation of the crops, as well as their origins and domestication. It covers genome relationships and crop wild relatives (CWR) in the *Brassica* genus and also notes the impact of a contested taxonomy, where species currently classified outside the *Brassica* genus may be more closely related to *Brassica* crops than are other species within the genus. The current *ex situ* conservation status of *Brassica* crops and CWR is summarized through an analysis of reported holdings, both those reported to databases such as Genesys-PGR and those described in the responses to a survey of 26 collection holders of *Brassica* crops.

Aims of the strategy

This conservation strategy for *Brassica* crops aims to highlight the current status of *ex situ Brassica* collections, and to identify where collaborative and rationalized efforts can improve the safeguarding of *Brassica* genetic resources. A series of priorities has been identified that will best benefit from a partnership approach with a shared vision. This will not only enhance the efficiency and effectiveness of conservation activities, but also ultimately ensure that *Brassica* germplasm is available to the user community.

Taxonomy and species covered

The Brassicaceae family covers 348 genera (including the *Brassica* genus) and approximately 3,700 species. A shared trait of Brassicaceae members is the production of secondary metabolites known as glucosinolates, as well as a characteristic flower morphology where four petals are arranged in the shape of a cross, leading to the original family name of Cruciferae. The *Brassica* genus has between 36 and 41 species, depending on the taxonomic treatment. The majority of these are not cultivated; however, six species are cultivated as crops of either local or global agricultural significance. This conservation strategy therefore focuses on these species: *Brassica rapa*, *Brassica oleracea*, *Brassica nigra*, *Brassica napus*, *Brassica carinata* and *Brassica juncea*. Within each species, different crop types have been selected, including vegetable-, oilseed-, condiment- and fodder-types. Across all *Brassica* crops, all parts of the plant are harvested: storage roots and stems, leaves, inflorescences and seeds. *Brassica* crops are diverse and include broccoli, cabbage, bok choy, turnip, kale, rapeseed and mustard. The degree of intraspecific variation is impressive, particularly within *B. oleracea* and *B. rapa,* where 14 and 15 sub-specific taxa have been described, each corresponding to a different crop type with its own unique morphology and characteristics. The morphologically diverse species have higher numbers of accessions stored in global *ex situ* collections, as assemblages of each morphotype have been built up in parallel (see Table 2).

Geographical distribution

The six most important *Brassica* species for agriculture are cultivated globally as oilseed crops, vegetables and condiments. They have moved with migration and trade away from their various centers of origin, and are cultivated on all continents apart from Antarctica. For example, rapeseed *(B. napus* and *B. rapa*) was grown in 63 countries in 2020, with the top producers being China, Canada and India (FAOSTAT 2022). *B. carinata* is another oilseed crop that is becoming more commonly cultivated outside its initial domestication center in North Eastern Africa due to its desirable oil composition and resilience in the face of abiotic stresses.

Significance: production and use

The United Nations Food and Agriculture Organization (FAO) has collated national and global production data for several categories of *Brassica* crops; rapeseed (oilseed), different vegetable types and mustards. Rapeseed production has increased markedly over the past 60 years, with a six-fold increase in its production area and a 10-fold increase in the production amount. For other *Brassica* crops, the production areas have remained relatively static, but the production quantities have increased over the same period. For example, the production of cabbage has almost tripled and that of cauliflower and broccoli has increased by five times. In terms of production quantity, rapeseed is second only to soybean as a source of vegetable oil. *Brassica* crops are of nutritional significance worldwide, being widely consumed sources of dietary micronutrients, minerals, dietary fiber and other beneficial compounds produced as secondary metabolites. Certain glucosinolates, such as glucoraphanin, have been shown to reduce inflammation, delay cancer progression, and improve cardiovascular health. Conversely, some glucosinolates are considered as anti-nutritional compounds in rapeseed meal, a byproduct of oil production that is fed to livestock. Breeding efforts have resulted in the development of canola, a type of rapeseed with low levels of glucosinolates and erucic acid, a fatty acid suspected of negatively affecting cardiovascular health.

Ex situ conservation of *Brassica* crops

A total of 70,241 accessions are reported as being conserved in genebank collections through the Genesys and World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS) information portals. Interestingly, a survey of collection holders indicated that the number of accessions held is significantly greater than the number reported; as their responses, combined with Genesys and WIEWS data, indicate that 85,474 accessions are held in collections. Unsurprisingly, the most widely cultivated species are best represented in genebanks (*B. rapa* – 21,398 accessions; *B. oleracea* – 21,041 accessions; *B. juncea* – 19,690 accessions and *B. napus* – 15,083 accessions). Far fewer accessions of *B. carinata* and *B. nigra* are held in genebanks (2,252 and 1,090, respectively), possibly because of geographical restrictions in their cultivation in the past. *Brassica* species have orthodox seeds, meaning that long-term conservation is possible under low-moisture and low-temperature (–20°C) conditions.

Current status and challenges for *ex situ* conservation of *Brassica* crops

A survey of 26 collection holders and a follow-up workshop indicated a series of common challenges for the efficient and effective conservation of *Brassica* germplasm in genebanks. A summary of considerations highlighted by collection managers through the survey and the workshop is presented below.

1. Regeneration

Regeneration was the most widely commented-upon aspect of the management of *Brassica* collections. As out-crossing species, *Brassica* crops require either sufficient space for isolation of accessions during regeneration or, ideally, isolation facilities such as pollination cages to prevent unwanted movement of pollen among accessions. Investment in financial, staff and physical resources would allow genebanks to undertake sufficient and effective regeneration of accessions. A further challenge is the regeneration of F_1 hybrid varieties released from breeding programs, because these cannot be propagated in the same manner as open-pollinated material. The lack of regeneration affects almost all aspects of collection management, from distribution to safety duplication, and is therefore the key to efficient and effective collection management.

2. Storage conditions

The survey responses indicated that 58% of collections are kept fully under long-term storage conditions (low moisture content, −20°C), with another 19% being partially maintained under long-term storage conditions. All but one of the remaining collections are at least partially kept under medium-term storage conditions. Storage conditions underpin effective collection management through minimizing the required regeneration frequency. The interpretation of short- and medium-term storage conditions was variable among respondents, although 96% of respondents reported that seeds are dried before storage, a process vital to improving seed longevity in storage.

3. Management of CWR

Genesys/WIEWS data indicate that 973 accessions of *Brassica* CWR are held in global germplasm collections, and the respondents to the survey reported 597 accessions. These species can be challenging to manage in germplasm collections, with long juvenile periods and particular environmental requirements that complicate regeneration. Some *Brassica* species are not represented in global collections at all, and others that are of conservation significance, such as *Brassica hilarionis* and *Brassica drepanensis,* are relatively poorly represented. These gaps require addressing, however the complex relationship among species in a polyphyletic taxon such as *Brassica* means that the significance of missing species for crop improvement programs is not always clear.

4. Documentation

Most collections reported the use of software to manage collection data, with 85% reporting that collection data are at least partly publicly available to users. Some collections reported the need to upgrade data management software, with two collections recognizing the need but not having the resources to do so. Efficient data management is critical for collection conservation and use. The software used ranged from the internationally supported GRIN-Global system to Microsoft Access as well as bespoke in-house systems. During the workshop, collection holders indicated they were not always best-placed to understand what software tools were available and to keep up with best practice.

5. Safety duplication

Safety duplication is a key activity to safeguard germplasm collections. There are several options available to collection managers: Storage of duplicates at another genebank within the country; storage of duplicates at another facility in a different country; and deposition of samples at the Svalbard Global Seed Vault (SGSV). Only two out of 26 survey respondents indicated that their collection is not duplicated at all, and 17 respondents indicated that their collection is at least partly duplicated elsewhere. In total, 13,277 accessions of *Brassica* crops are held at the SGSV. During the workshop, it was recognized that safety duplication is intrinsically linked to regeneration and that duplicates should be high-quality seeds with the highest viability.

6. Distribution

Most of the survey respondents (92%) reported that they are able to distribute materials from their collections, with 92% of distributions being covered by a Standard Material Transfer Agreement (SMTA) or another contractual document. The survey respondents indicated a stable or increasing outlook for the distribution of seed samples. Constraints included the resources to regenerate enough seeds, as well as the impact of more stringent phytosanitary regulations and the requirement for testing and certification to meet a range of national import requirements.

Strategic priorities for *ex situ* conservation of *Brassica* crops and related wild species

Further investment and improvement is required to safeguard and ensure the efficient and effective conservation of *Brassica* germplasm in global collections. There is no single genebank with sole responsibility for *Brassica* crops as they are a diverse collection of crop types, therefore material is distributed among many national and other collections. The following equally weighted priorities were identified:

1. Assistance and resources for regeneration

Regeneration was reported as a key limiting factor for many genebanks, as it underpins many other collection management activities. Funds and resources should be directed to those collections who currently cannot carry out sufficient regeneration. Other options include assistance from better-resourced genebanks or in-kind partnerships with other organizations such as commercial plant breeding companies.

2. Identification of unique materials for priority conservation

Understanding collection gaps depends on a clear knowledge of what is already present in collections. With incomplete descriptive passport data and a lack of characterization and genotype/sequence data, this is not always clear. A joint program aimed at understanding uniqueness is required to identify priority materials and ensure their conservation, as well as highlighting gaps in global collections.

3. Documentation – making information available to users and managers

Discussions during the workshop indicated a lack of confidence among some collection managers about the best way to manage data, and how to select the best software tools to do so. This could be overcome by sharing experiences and engaging in discussions to find solutions, as well as by developing links with other organizations involved in genebank data management.

4. CWR

A coordinated gap analysis of Brassica CWR in global collections is required, pulling together information on material not currently listed in Genesys/WIEWS and data on the availability of material that is listed. This will identify key gaps to target for future collections, and further highlight key germplasm already in the global collection. Work has already started on a wider gap analysis of the Brassicaceae family, and it will be important to build on this analysis. The issue of regeneration for this group of species is also important to address.

5. A Global Brassica Plant Genetic Resources Network

Many of the issues highlighted in the survey and during the discussion would benefit from a collaborative approach to the sharing of information, methods, and where appropriate, tasks. An organized network allowing for communication among collection managers on issues such as gaps, regeneration, information management, phytosanitary issues and other matters will provide a much-needed means of peer support among collections and assist in making the best use of any future investment in ex situ conservation of Brassica materials.

Photo: Tennisons Photography

Canola field in Victoria, Australia.
Photo: Michael Major

1 INTRODUCTION

1.1 Rationale

As part of an initiative led by the Global Crop Diversity Trust (the Crop Trust) and funded by the Federal Ministry of Food and Agriculture of Germany (BMEL), a strategy has been developed for the conservation and use of genetic resources of crops in the *Brassica* L. genus. This strategy starts with an overview of *Brassica* crops and their wild relatives, continues with an assessment of the current status of *ex situ* conservation of *Brassica* genetic resources, and concludes by outlining recommendations and priority activities to improve the global system for the conservation of *Brassica* genetic resources.

1.2 Methods and data sources

This strategy was developed between December 2021 and October 2022, facilitated by C. Allender of the Warwick Genetic Resources Unit, Warwick University, and coordinated by Peter Giovannini of the Crop Trust. Information provided in the section "Overview of *Brassica* crops and their wild relatives" has been summarized from online databases and published literature, as well as from conversations with collection holders.

Data on the *ex situ* conservation of *Brassica* crops and their wider genepool were gathered from online databases, a survey directed to curators of *Brassica ex situ* collections (Appendix 1), and consultation meetings with *Brassica* genetic resources stakeholders (Appendix 2, Stakeholders' meetings participants). More specifically, information on *Brassica* was retrieved from the following online genetic resource databases: the Genesys Plant Genetic Resources Portal (Genesys 2022), the World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS) of the United Nations Food and Agriculture Organization (FAO) (FAOSTAT 2022), and the Svalbard Global Seed Vault (SGSV) Seed Portal (SGSV 2022).

Brassica genetic resource stakeholder (online) meetings were conducted on the 23–24 June 2022 (Appendix 2), and were attended by 13 participants from 11 countries. The survey results were presented and the following topics were discussed: collection gaps, documentation, regeneration, safety duplication, characterization, distribution and seed health.

Based on the information and data gathered as described above, a strategy was drafted and circulated to stakeholders. Inputs from stakeholders were integrated into the draft, which was then reviewed by the Crop Trust.

Photo: Charlotte Allender

2 OVERVIEW OF *BRASSICA* CROPS AND THEIR WILD RELATIVES

2.1 Agricultural and economic significance

Brassicas are significant crops, both agriculturally and economically. They are cultivated as vegetables, condiments and oilseeds. Examples include cabbages, cauliflowers, turnips, pak choy, mustards and rapeseed. Different varieties of rapeseed yield oils suitable for consumption, biofuel, lubricants, and other industrial and pharmaceutical products. An additional and growing use is as a biofumigant crop, offering another means of managing agricultural pests and diseases. A summary of the FAO production data for a range of different *Brassica* crop types is presented in Table 2.1. Figure 2.1 shows the global trend in harvested area and production between 1961 and 2020. The diversity of crop types within *Brassica* means that production is reported separately. In terms of vegetable oil production, rapeseed is the second largest source globally, second only to soybean (FAOSTAT 2022). *Brassica* crops are grown on every continent due to their diversity of form and collective ability to tolerate a wide range of environmental conditions.

2.2 Taxonomy

The genus *Brassica* is part of the Brassicaceae, a diverse and species-rich family with about 3,700 species. The Brassicaceae family sits within the order Brassicales, along with 16 other families covering about 4,700 species, the majority of which share the trait of producing glucosinolates as secondary metabolites (Franzke et al. 2016). The Brassicaceae family is a diverse family of species in 348 genera. A common

Table 2.1 2020 global area harvested and production quantities for various Brassica crops (FAOSTAT 2022).

Crop type	Area harvested (km^2)	Production (Mt)
Cabbage and other *Brassica* vegetables	24,142.9	70.9
Cauliflower and broccoli	13,571.9	25.5
Mustard seed	6,195.0	0.5
Rapeseed	354,965.3	72.4

characteristic of the family is the flower morphology; flowers exhibit four sepals, four alternating petals, and four long and two short free stamens. The petals are arranged in the shape of a cross, which gave the family its previous name (Cruciferae). The Brassicaceae family also contains the extensively researched model species *Arabidopsis thaliana*, the first plant species to have its genome fully sequenced. *A. thaliana* has underpinned fundamental research on the structure and function of plant genes. The relatively close evolutionary relationship between *Brassica* crops and *A. thaliana* means that genetic and genomic research in *Brassica* has benefited enormously from the knowledge base assembled for the model species. One of the factors supporting the radiation (development of many species) of the Brassicaceae family is a pattern of whole genome duplication events, which appear to have driven novel adaptation and speciation (Schranz et al. 2012). These genome duplications can be observed in *Brassica* species, where diploid genomes have undergone a triplication event – multiple copies of genes mean that their structure and function can diverge. The diversification of Brassicaceae species has been dated to between 31.8–37.5 million years ago (MYA) (as discussed in Franzke et al. 2016 and references therein). The Brassicaceae family has been divided into 25–30 tribes, including the tribe Brassiceae. There are five to seven distinct lineages within the tribe Brassiceae, with currently accepted genera falling into more than one lineage in some cases, indicating incongruence between the current taxonomic classification and molecular evidence (see Gupta (2016) for a summary).

2.3 The *Brassica* genus

The taxonomy of the *Brassica* species complex, and the contradictions between currently accepted taxonomic treatments and molecular evidence in particular, are summarized in Gupta (2016) and references therein. *Brassica* species fall into two separate lineages of the Brassiceae tribe; the Rapa/Oleracea lineage and the Nigra lineage. Both lineages contain species from other genera, such as *Diplotaxis*, *Raphanus* and *Eruca* (Warwick and Black 1991). Excluding hybrid species, there are 41 accepted *Brassica* species as listed in the

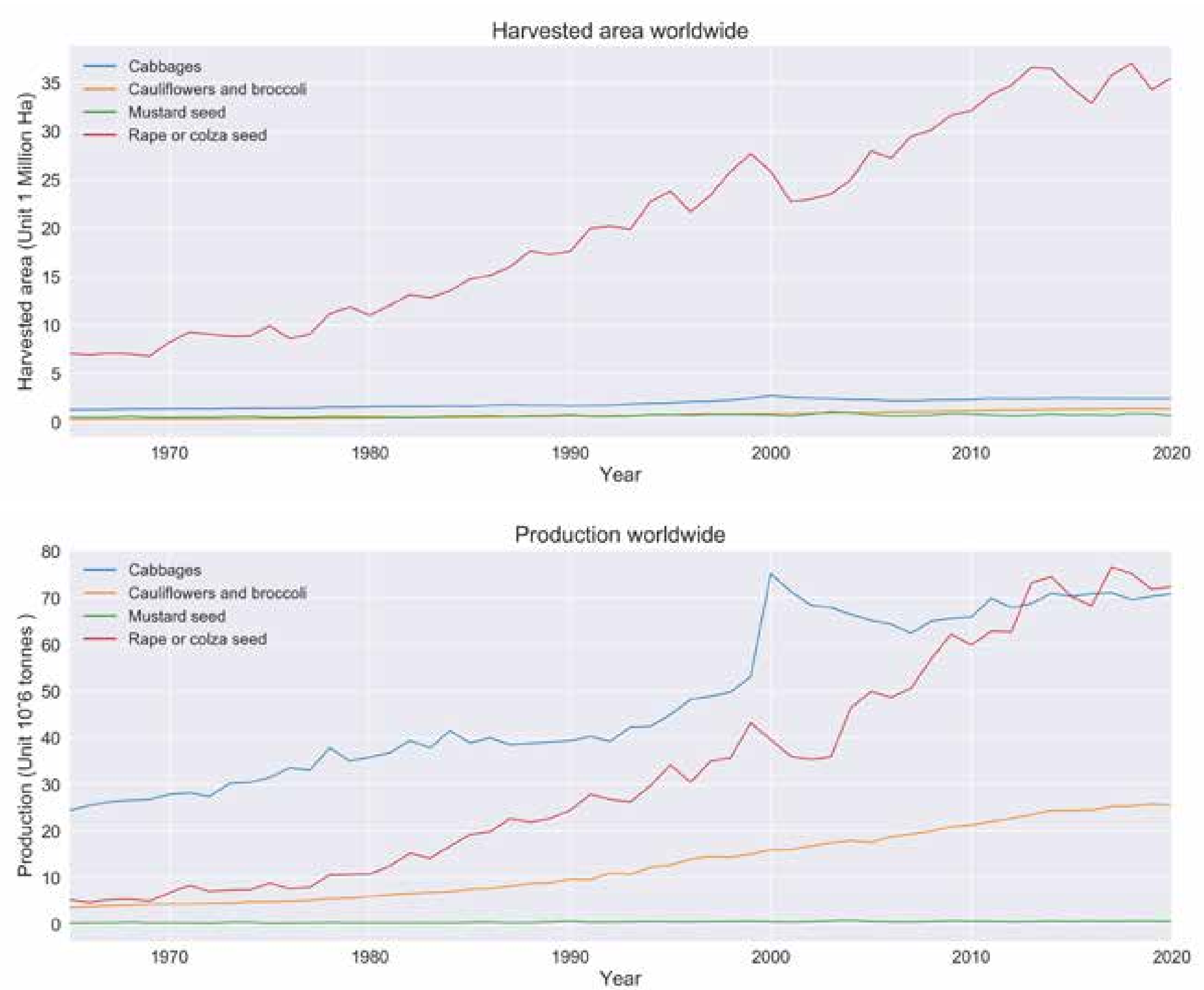

Figure 2.1 Global harvested area of different *Brassica* crops (top), and their global production (bottom). Data from FAOSTAT (accessed on 10 October 2022

Plants of the World Online database (POWO 2022), or 36 as listed in the Germplasm Resource Information System (GRIN) Taxonomy database (USDA 2022).

There are six agriculturally and economically significant crops in the *Brassica* genus. These crops are cultivated globally and are consumed in a range of ways, from oil to condiments or as a vegetable. Those consumed as a vegetable show an impressive range of morphological diversity – the result of local selection and adaptation during the cultivation history of the crop. Three of the six most commonly cultivated *Brassica* species have diploid genomes, the other three are amphidiploid; i.e., their genomes comprise different combinations of the three diploid genomes. The genomic relationships among the six commonly cultivated species have been described by Nagaharu and Nagaharu (1935), who identified the different diploid genomes and the combinations of these genomes in the amphidiploid species (Figure 2.2). The progenitor genomes are identified as the A genome (*B. rapa*), the B genome (*B. nigra*) and the C genome (*B. oleracea*). The amphidiploid species would have arisen as spontaneous inter-specific hybrids in geographical regions where the two progenitor species overlapped. This process requires chromosome doubling to produce stable, fertile amphidiploid progeny; this could have occurred *via* the production of unreduced (diploid rather than haploid) gametes by the progenitor species (Dar et al. 2017).

2.4 Biochemistry, and human and plant health

Brassica crops contribute significantly to global nutrition. As vegetables, they are important sources of vitamins such as vitamins C, A and E and essential minerals such as calcium and potassium (Sanlier and Guler 2018), as well as other components, such as dietary fiber. Some *Brassica* vegetables are excellent accumulators of selenium, offering a means to combat dietary deficiencies. Oilseed brassicas are sources of monounsaturated fatty acids such as oleic acid, as well as polyunsaturated fatty acids such as alpha-linolenic acid; both classes of fatty acids have a desirable impact on health-related blood lipids (Aukema and Campbell 2011). However, not all the fatty acids present in *Brassica* seed oil are beneficial to health. The breeding history of *B. napus* has involved selection for low levels of erucic acid, a monounsaturated fatty acid shown to adversely impact health in animal models (Downey 1964).

The secondary metabolites produced by *Brassica* plants can also have significant health benefits. One major class of secondary metabolites is the glucosinolates, compounds that contain nitrogen and sulfur combined with glucose and one or more amino acids. Up to 137 glucosinolates have been putatively identified (Blažević et al. 2020). The three major classes are aliphatic, indole and aromatic glucosinolates. They are

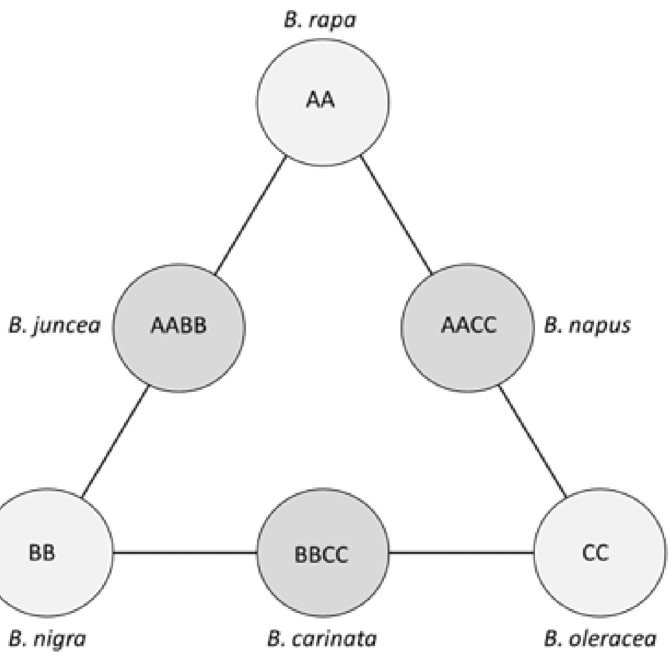

Figure 2.2 Genome relationships in cultivated Brassica as described by Nagaharu and Nagaharu (1935).

secreted into storage vacuoles within plant tissues in a biologically inactive form. Damage to the leaf, for example by insect herbivores, releases the glucosinolates and brings them into contact with the enzyme myrosinase. The glucosinolates are then hydrolyzed and converted into a biologically active molecule, for example, an isothiocyanate. Isothiocyanates are highly biologically active, and have antimicrobial and insecticidal properties, as well as favorable impacts on cardiovascular health, inflammation and cancer development and progression (Maina et al. 2020). Conversely, the high concentrations of glucosinolates in meal left over from processing oilseed *Brassica* crops, particularly *B. napus*, confer antinutritional properties and result in poor palatability, leading to negative impacts on growth and thyroid function when fed to livestock (Griffiths et al. 1998). This, along with the requirement to limit erucic acid levels in rapeseed oil due to potentially detrimental impacts on health, led to the development of the first so-called "double low" varieties, and the new crop name "canola" in Canada in the 1970s (Stefansson and Kondra 1975).

The presence of glucosinolates and other secondary metabolites with biocidal actions against a range of microbial and invertebrate organisms has led to the further development of *Brassica* crops as biofumigants. When they are used in this way, the *Brassica* plants are grown, macerated and incorporated into the soil, where glucosinolates released from plant tissues break down into bioactive compounds that can control populations of microbial pathogens (Tagele et al. 2021) and invertebrate pests (Ahuja et al. 2010). Biofumigation offers an alternative method of pest and pathogen control, thereby reducing reliance on environmentally damaging synthetic pesticides. Work has also been undertaken to produce cover crop mixtures consisting of *Brassica* and other cruciferous crops with a biofumigant effect and other species (Couëdel et al. 2018). Multiple soil health benefits have been proposed, including enhanced soil nutrient status and decreased erosion.

2.5 Major *Brassica* crops

There are six major *Brassica* crops, as listed below.

***B. rapa* L.** (A genome, 2n = 2x = 20). This commonly cultivated species exhibits impressive morphological diversity, and is cultivated for a variety of purposes, including as a vegetable and oilseed. Depending on the vegetable type grown, the leaves, floral buds or storage root may be consumed, and there is further wide variation in its growth habit (heading or open) and leaf morphology. The crop types have been classified into subspecies based on their morphological characteristics or use. Eight subspecies are described for vegetable types (Table 2.2). The vegetable types differ in their leaf traits, such as the enlarged petiole seen in bok choy through to the more delicate leaves of mizuna, which are cooked lightly or eaten in salads. Turnips are root vegetables formed from the storage root and the adjoining stem. Oilseed types are grouped into three further subspecies according to differences in their geographical origin and seed traits.

Molecular phylogenetic analyses indicate that *B. rapa* was initially domesticated in Central Asia between 3,430 and 5,930 years before present (YBP) (McAlvay et al. 2021). The first cultivated types were turnip- and/or oilseed-types, with diversification of crop types occurring in different locations in the Mediterranean region and East Asia. Wild and weedy forms appear

Table 2.2 Subspecies and subtaxa of cultivated *B. rapa* with corresponding common name (USDA 2022).

Taxon	Crop type/common name
subsp. *chinensis* (L.) Hanelt	Bok choy
subsp. *chinensis* (L.) Hanelt var. *parachinensis* (L. H. Bailey) Hanelt	Choy sum
subsp. *chinensis* (L.) Hanelt var. *purpuraria* (L. H. Bailey) Kitam.	Purple-stem mustard
subsp. *dichotoma* (Rox*B.*) Hanelt	Brown *sarson/Toria*
subsp. *japonica* Shebalina	
subsp. *narinosa* (L. H. Bailey) Hanelt	Tatsoi
subsp. *nipposinica* (L. H. Bailey) Hanelt	Mizuna/mibuna
subsp. *nipposinica* (L. H. Bailey) Hanelt var. *perviridis* L. H. Bailey	Komatsuna
subsp. *oleifera* (DC.) Metzg.	Turnip rape
subsp. *oleifera* (DC.) Metzg. f. *annua* (Metzg.) Thell.	Spring turnip rape
subsp. *oleifera* (DC.) Metzg. f. *biennis* (Metzg.) Thell.	Winter turnip rape
subsp. *oleifera* (DC.) Metzg. var. *ruvo* (L. H. Bailey) Gladis & K. Hammer	Broccoli raab
subsp. *pekinensis* (Lour.) Hanelt	Chinese cabbage
subsp. *rapa*	Turnip
subsp. *trilocularis* (Rox*B.*) Hanelt	*Sarson*

globally, however populations in Central Asia appear to be the most diverse. Other wild and weedy populations cluster very closely with cultivated types, indicating that they are of feral origin. There is evidence of multiple origins of similar crop types in different geographical regions, particularly oilseed- and turnip-types (Bird et al. 2017).

***B. oleracea* L.** (C genome 2n=2x=18). This species is cultivated as a wide range of vegetables, with different crops characterized by the development of different plant organs. There are 14 different crop types currently recognized by the USDA (2022) (Table 2.3). Notable morphologies include proliferated floral meristems (broccoli and cauliflower), a tightly packed head of leaves (cabbages, including savoy cabbage), a swollen storage stem (kohlrabi) and enlarged axillary buds (Brussels sprouts). The diversity of *B. oleracea* crops has intrigued researchers for many years and has led to multiple hypotheses about the domestication event or events that resulted in this array of crop types. *B. oleracea* shares the 2x=18 C genome with several other species (see the stratification diagram).

Many studies have explored the domestication origin of *B. oleracea* crops, using morphological (Nieuwhof 1969; Wellington and Quartely 1972), genetic (Golicz et al. 2016; Perumal et al. 2021; Cai et al. 2022) and linguistic information (Maggioni et al. 2010; Maggioni et al. 2018). An in-depth survey of genetic variation using single nucleotide polymorphic (SNP) markers indicated that the closest relative of cultivated forms is *Brassica cretica* (Mabry et al. 2021). The results of that study indicated that European populations of wild *B. oleracea* may in fact be feral escapes from cultivation, as suggested previously by Mitchell (1976), and that the genetically and morphologically diverse *B. cretica* appears to be the common ancestor of contemporary cultivated forms.

***B. nigra* (L) Koch** (B genome 2n = 2x = 8). The lineage leading to *B. nigra* is thought to have diverged from the *B. rapa*/*B. oleracea* lineage 11.5 MYA (Perumal et al. 2020). *B. nigra* was originally cultivated as an oilseed and spice crop, with a probable origin in the area of Asia Minor and Iran (Hemmingway 1976). It was widely grown across many regions, including Europe, Asia, Africa and the Indian sub-continent, due to its commercial value as a spice crop. However, the high levels of seed shattering (requiring hand harvesting) among early cultivars meant that it was replaced by *B. juncea* during the mid-twentieth century (Hemmingway 1976). Consequently, compared with other *Brassica* species, *B. nigra* as a whole has undergone less selection pressure through formal breeding programs. It is designated as a harmful invasive species in some parts of its introduced range (Pakpour and Klironomos 2015).

***B. carinata* A. Braun** (BC genome 2n = 4x = 34). *B. carinata* is thought to have arisen from a spontaneous hybridization between *B. nigra* and *B. oleracea* in North-eastern Africa 4000–5000 YBP (Song et al. 2021). The primary center of diversity of this crop seems to be in Ethiopia, where it was likely first domesticated. It is grown in several forms; as oilseed-, leafy vegetable-, condiment- and fodder-type crops. More recently, it has been grown as feedstock for bioenergy and plastics production (Seepaul et al. 2021). As a crop, *B. carinata* has several desirable agricultural traits, such as resilience to drought and heat, resistance to lodging, and resistance to various pests and diseases. These traits make it more suitable than other *Brassica* species for cultivation in hot and dry regions.

Table 2.3 Subtaxa of *B. oleracea* with their corresponding common name or crop type (USDA 2022).

Taxon	Crop type/common name
var. *alboglabra* (L. H. Bailey) Musil	Chinese kale/Kailan
var. *botrytis* L.	Cauliflower
var. *capitata* L.	Cabbage
var. *costata* DC.	*Tronchuda* cabbage/kale
var. *gemmifera* DC	Brussels sprouts
var. *gongylodes* L	Kohlrabi
var. *italica* Plenck	Broccoli
var. *medullosa* Thell.	Marrow stem kale
var. *oleracea*	Wild species
var. *palmifolia* DC.	Jersey kale
var. *ramosa* DC.	Thousand head kale
var. *sabauda* L.	Savoy cabbage
var. *sabellica* L.	Curly kale
var. *viridis* L.	Collard greens

***B. juncea* (L.) Czern.** (AB genome 2n = 4x = 36). *B. juncea* is classified into four subspecies based on its use and crop morphology (Table 2.4). Seed mustard is grown as an oilseed and a condiment, while leaf mustards vary in form and are important leafy vegetables that are either cooked or consumed as a salad. Root mustards tend to be grown in Northeast China and Mongolia and are the most cold-tolerant of the *B. juncea* crops. *B. juncea* originated as a species 8000–14000 YBP in West Asia. A polyphyletic origin has been proposed based on analyses of chloroplast genetic markers (Kaur et al. 2014). Genetic analysis indicates that three independent domestication events took place 500–5000 YBP (Kang et al. 2021). The contemporary geographical range of *B. juncea* is very wide, covering Africa, Asia, Europe, America and Australia. It is a significant oilseed crop particularly in Bangladesh, India, Ukraine and China; the latter country holds the highest diversity of all *B. juncea* crop types (Dixon 2007).

***B. napus* L.** (AC genome 2n = 4x = 38). *B. napus* is a globally significant oilseed crop. Rapeseed (primarily *B. napus*) is second only to soybean as a source of vegetable oil with 72.4 Mt rapeseed produced globally in 2020 (Table 2.1, FAOSTAT 2022). Oil produced from *B. napus* is mainly used in the food industry, but different varieties have been developed that are suitable for the production of biodiesel and other oils for the industrial, cosmetic and pharmaceutical industries (Aukema and Campbell 2011). Genomic evidence indicates that *B. napus* arose through hybridization between *B. rapa* and *B. oleracea* 7500 YBP (Chalhoub et al. 2014). The maternal lineage was a European *B. rapa* turnip and the paternal lineage was an ancestor of the current *B. oleracea* vegetable group (Lu et al. 2019). No truly wild populations are known, making it challenging to ascertain the exact evolutionary history of this species. *B. napus* is now cultivated in several forms that vary in their morphology, use, and flowering behavior (annual or biennial) as shown in Table 2.5.

2.6 Minor *Brassica* crops

Other species in the *Brassica* genus are cultivated and have local significance in particular areas. One example is *Brassica tournefortii* (African mustard or Asian mustard). This species is particularly suited for growth in dry conditions, for example, the drier areas of Northern India (Singh et al. 2015); however, it has been displaced by other oilseed crops that are better suited to cultivation. A recent study explored its potentially beneficial secondary metabolites (Rahmani et al. 2019). However, despite its beneficial uses, *B. tournefortii* is regarded as a damaging invasive species in some countries, including the USA and Australia (CABI 2022). Other *Brassica* species, such as *Brassica fruticulosa* in Sicily, have a long history of cultivation as a food, and work has been undertaken to optimize cultivation methods (Branca and Fisichella 2003).

Table 2.4 Major cultivated subspecies of *B. juncea* (USDA 2022).

Taxon	Crop type/ common name
subsp. *juncea*	Seed mustard
subsp. *napiformis* (Pailleux & Bois) Gladis	Root mustard
subsp. *integrifolia* (H. West) Thell.	Leaf mustard
subsp. *tsatsai* (T. L. Mao) Gladis	Stem mustard

Table 2.5 Major cultivated types of *B. napus* (USDA 2022).

Taxon	Crop type/common name
subsp. *napus* f. *annua* (Schübl. & G. Martens) Thell.	Spring oilseed
subsp. *napus* f. *napus*	Winter oilseed
subsp. *napus* var. *pabularia* (DC.) Alef.	Siberian kale
subsp. *rapifera* Metzg.	Swede/Rutabaga

Photo: Charlotte Allender

3 *EX SITU* CONSERVATION OF *BRASSICA* CROPS AND THEIR WILD RELATIVES

3.1 Storage of *Brassica* seeds

Brassica species have orthodox seeds in terms of conservation; the seeds can be dried to a low moisture content (typically 5% moisture content by weight) and stored at low temperatures such as −20°C (Roberts 1973). The lifespan of seeds stored under these conditions can be measured in decades, however, different studies have shown remarkably different outcomes of long-term seed storage. A baseline recommendation to store seeds at −20°C with a seed moisture content of 5% (+/-1%) was made by the International Board of Plant Genetic Resources (IBPGR 1976), and was echoed by the FAO in a guideline set of standards for genebanks (FAO 2014). A study of seeds conserved within the United States Department of Agriculture National Plant Germplasm System indicated that those of *Brassica* species were relatively short lived, with the estimated time to reach 50% viability ranging from 23 to 59 years depending on the species (Walters et al. 2005). In contrast, a study on 15 accessions of Brassicaceae species (including two *Brassica* species) found very little loss of viability after 40 years in storage (Pérez-García et al. 2009), with longer storage periods improving germination test results through the removal of seed dormancy. It is likely that ensuring a low-oxygen environment, such as that achieved through vacuum packaging, will further enhance the lifespan of seeds (Groot et al. 2015). Optimal storage conditions enhance seed longevity, reducing the need for regeneration procedures, which are both costly and potentially risk genetic drift from the allelic composition of the original sample.

3.2 Current *ex situ* conservation of *Brassica* genetic resources – size of collections.

There are extensive collections of *Brassica* germplasm conserved around the world. An assembly of *Brassica* passport data from 150 genebanks was compiled using data from Genesys (Genesys 2022) and FAO-WIEWS (WIEWS 2022) databases (hereinafter, we refer to this dataset as the combined WIEWS/Genesys dataset). Additionally, data on the size of the collections of the six main cultivated *Brassica* species were collated through a survey (see section 3.3).

According to the combined WIEWS/Genesys dataset, 70,241 accessions of *Brassica* seeds are conserved in 150 institutes in 81 countries, and 31,644 of these are included in the Multilateral System (MLS) of The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). When the data obtained through the survey (section 3.3) are also considered, the total number of estimated *Brassica* accessions conserved *ex situ* at the global level increases to 85,474. These accessions cover 36 species (excluding interspecific hybrids), although the vast majority (94% of the total) represent the six most commonly cultivated species; *B. oleracea*, *B. napus*, *B. rapa*, *B. juncea*, *B. nigra* and *B. carinata* (see Table 3.1). This is unsurprising given the nature of crop genetic resources and the outputs of crop breeding around the world. The size of collections is highly variable, ranging from a single accession (14 institutes) to 13,364 accessions in the largest collection. The mean collection size is 471 accessions. Eighteen institutes have more than 1,000 accessions in their collections.

It is helpful to consider the holdings of the major crop species when assessing the status of the global *Brassica* collection. Table 3.1 shows the breakdown of the global *Brassica* collection in terms of the six major species. It is clear that two species, *B. nigra* and *B. carinata*, have almost ten-fold fewer accessions in the global collection than the other four. This is likely due to the relative lack of cultivation, or restricted distribution of cultivation, of these species (Hemmingway, 1976).

Figure 3.1 shows the 16 largest collections of each of the six main cultivated species (except *B. carinata,* for which only the top 13 are shown), and the numbers of accessions conserved, according to data from both from the combined WIEWS/Genesys dataset and the survey of *Brassica* collection holders (see section 3.3). Interestingly, different collections seem to have different focal crops in terms of the global total. The largest *B. oleracea* collection is held by the UK Vegetable Genebank (GBR006 – 3,394 accessions). The National Bureau of Plant Genetic Resources in India (IND001) holds the largest collections of both *B. rapa* and *B. juncea* (4,693 and 7,909 accessions, respectively). The sizes of *B. nigra* collections are much smaller, reflecting its relatively minor status globally; the largest collection of 225 accessions is held by the Australian Grains Genebank (AUS165). The same organization holds the largest collection of *B. napus* (1,478 accessions). The largest collection of *B. carinata* by far is held in Ethiopia at the Ethiopian Biodiversity Institute (ETH085, 639 accessions). The location and size of the largest 20 collections of each crop are additionally shown in Tables 1–6 in Appendix 3. For each cultivated species, a choropleth map was generated using data from the combined WIEWS/Genesys dataset, showing the number of accessions recorded as landraces by country of origin.

3.3 Survey of *Brassica* collection holders

To better understand the dynamics, priorities and vulnerabilities within existing *Brassica* plant genetic resource (PGR) collections, collection holders were surveyed on various aspects of collection management and practice, as well as issues impacting conservation. *Brassica* collection holders were identified based on information at the Genesys and WIEWS databases. Collections holding more than five *Brassica* accessions were contacted in February 2022 to invite them to take part in the development of the strategy and complete the survey document (Appendix 1). Twenty-six collection managers responded, a response rate of 24.7%. The respondents are based in 23 countries (Figure 3.2). A range of organization types are represented, including 17 government or government-affiliated organizations, five universities, three non-governmental organizations and one intergovernmental organization.

Survey respondents were invited to take part in one of two online workshops held on 23 and 24 June 2022 (Appendix 2). The agenda for both workshops was identical; two separate meetings were held to allow participation of survey respondents in different time zones. The outline results of the survey were presented and discussed with a view to shaping strategic priorities for the conservation of *Brassica* genetic resources.

The survey and workshops identified several common themes which, if addressed, would enable safe, effective and efficient *ex situ* conservation of *Brassica* germplasm. Future work and resources should be targeted to enable collection holders to address areas of concern within these themes to safeguard their collections and make them available for distribution.

Table 3.1 Estimated size of the global collection of the six main cultivated Brassica species. Data sourced from the combined WIEWS/Genesys dataset (2022). Total estimates are based on data from the combined WIEWS/Genesys dataset and data obtained through the survey of Brassica collection holders (2022).

Species	Global holdings based on combined WIEWS/Genesys dataset (2022)	Global holdings based on combined WIEWS/Genesys dataset (2022) + Survey 2022
B. rapa	18,341	21,398
B. oleracea	17,778	21,041
B. juncea	14,583	19,690
B. napus	12,201	15,083
B. carinata	1,944	2,252
B. nigra	996	1,090
Total	65,843	80,554

Regeneration

Due to the outcrossing nature and self-incompatibility of some *Brassica* crops (particularly *B. oleracea*), regeneration procedures and facilities need to be able to handle a sufficient number of individual plants to maintain intra-accession diversity, and to maintain the genetic integrity of each accession through avoiding cross-pollination between accessions. This is normally achieved by enclosing plants and pollinators in isolation compartments, or by ensuring that there is sufficient physical distance between field plots to reduce the likelihood of pollen movement among accessions. An additional challenge discussed by the workshop participants was the regeneration of vegetable-type crops compared with oilseed-type crops, the latter being selected for seed production and the former often being selected for delayed bolting and flowering.

Regeneration of *Brassica* germplasm was consistently identified as a limiting factor in both collection management and distribution by both survey respondents and by the discussions held in the workshops. Eleven out of 26 respondents mentioned regeneration specifically when asked about the top three vulnerabilities of their collection. One collection holder indicated that no resources were available for regeneration at all, meaning that distribution of samples was not possible.

Another factor impacting regeneration discussed at both workshops was that new commercial varieties of *Brassica* crops are likely to be F_1 hybrids. This type of cultivar offers superior uniformity and potentially superior agronomic characteristics; however, without the parental lines used to produce the variety, it cannot be maintained as an F_1 within genebank collections. Conservation of highly developed material such as F1 hybrid varieties offers the possibility of conserving useful combinations of alleles in a crop form which can more easily be utilised by breeders. Such allels may be present individually in more diverse germplasm but moving alleles from less developed material into elite breeding lines is potentially a lengthy process. Depending on the method used to control pollination (self-incompatibility or cytoplasmic male sterility to ensure only hybrid seed is produced from the parental lines), it may be possible to maintain the alleles present in the original F_1 hybrid as an F_2 population. This is only a possibility with F_1 hybrid varieties developed using self-incompatibility as a means of controlling hybridization; a fertility restorer line is required for cytoplasmic male sterility, and these (along with parental lines) are unlikely to be made available to genebanks for commercial reasons. Therefore, there is a potential problem with the long-term conservation of F_1 hybrid *Brassica* crops in genebanks; seeds from F_1 hybrids can be conserved under long-term storage conditions but their true-to-type regeneration may not be possible.

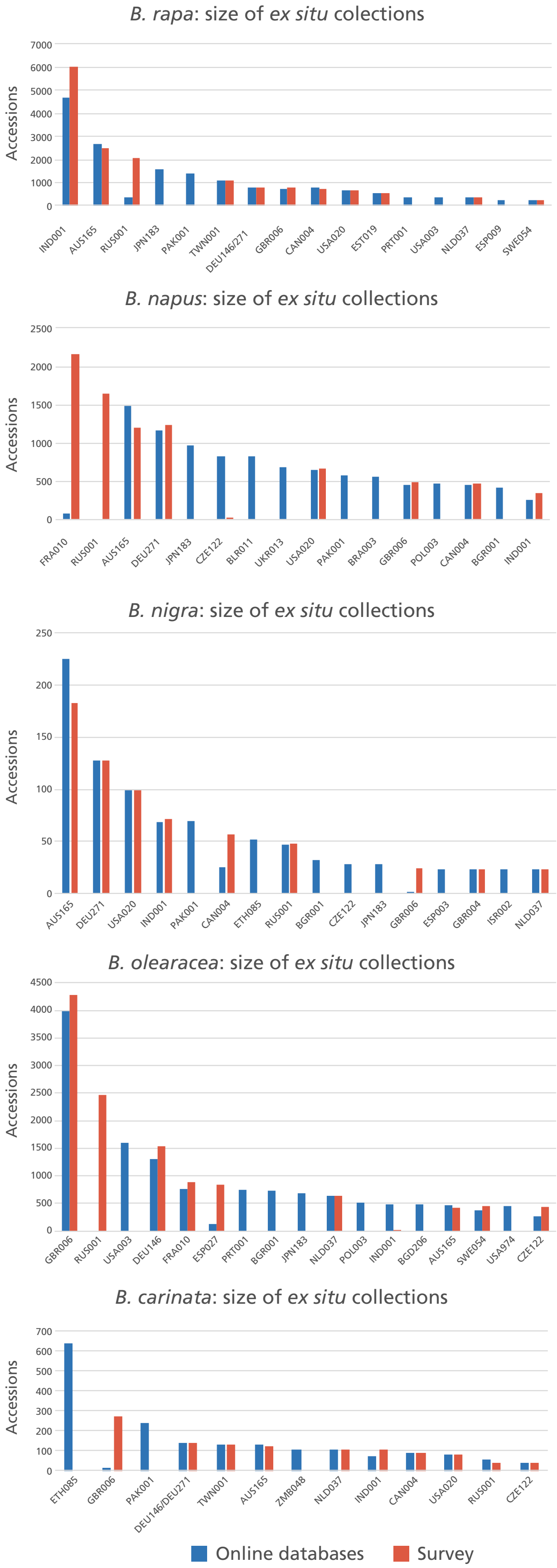

Figure 3.1 Size (number of accessions) of the 16 largest collections of the six main cultivated *Brassica* species (except for, *B. carinata*, for which 13 largest collections are shown). Collection holder is identified by the WIEWS institute code, and includes the ISO three letter code for the host country. Refer to the relevant table in Appendix 3 for the organization name in full. Data were obtained from the combined WIEWS/Genesys dataset (2022), and the survey of *Brassica* collection holders (2022).

Many of the other factors identified as a vulnerability to *Brassica* collections in the survey also potentially relate to regeneration. Adequate financial resources, space and facilities, and staff are required to carry out sufficient regeneration activities to maintain overall viability. These factors were noted by five respondents each. Potential genetic impacts on conserved material were also identified as issues. Genetic erosion, seed aging and a loss of genetic integrity could all be unwanted outcomes of inadequate regeneration frequencies, facilities and procedures. Regeneration was seen as an opportunity to rationalize collections by two respondents, allowing prioritization of important material. Several collection holders linked the regeneration capacity to safety duplication, as duplicates should be recently regenerated high-quality seeds rather than seeds sub-sampled from those that may have been stored for many years.

Safety duplication

Safety duplication of samples is a vital safeguard for the long-term conservation of crop genetic diversity. Ideally, safety duplication involves the storage of a high-quality subsample of an accession in long-term storage in a different country, providing a means of avoiding collection loss due to socio-political factors or major natural catastrophe. The majority of respondents to the survey (14) indicated that their collection is partly safety duplicated, and a further three respondents indicated that their collection is fully safety duplicated elsewhere. Only two collections indicated that they are not safety duplicated at all, and a further two respondents did not answer the question.

Seventeen respondents indicated that their collections are safety duplicated outside their country, either in the SGSV (nine respondents), as a ‘black box’ duplicate (five respondents), or fully integrated into another collection (three respondents). Some collections are safety duplicated in a central national facility. Constraints to safety duplication included seed quantity and resources for regeneration (one collection), national regulations, and restrictions due to phytosanitary requirements.

The SGSV allows collection holders to safety-duplicate their samples in an international facility. Currently, 26 *Brassica* collections have deposited materials at the SGSV; in total, 13,277 accessions with distinct accession numbers are duplicated there (Table 3.2). However, only one collection is 100% duplicated at the SGSV (determined by comparing the WIEWS/Genesys dataset with SGSV holdings as recorded in the SGSV seed portal (SGSV 2022). The range of coverage of collections is <1%–100%, with a mean of 34% and a median value of 33.3%. Figure 3.3 shows the distribution of the estimates of safety duplication in 21 *Brassica* collections.

The topic of safety duplication was discussed at the workshop. The need for safety duplication as a part of good collection management was recognized. Several collections linked regeneration to safety duplication; they reported that they use subsamples of regenerated seeds as a safety duplicate, ensuring that the duplicate samples have high viability and the longest possible lifespan. Therefore, safety duplication of these collections is more of a process than a

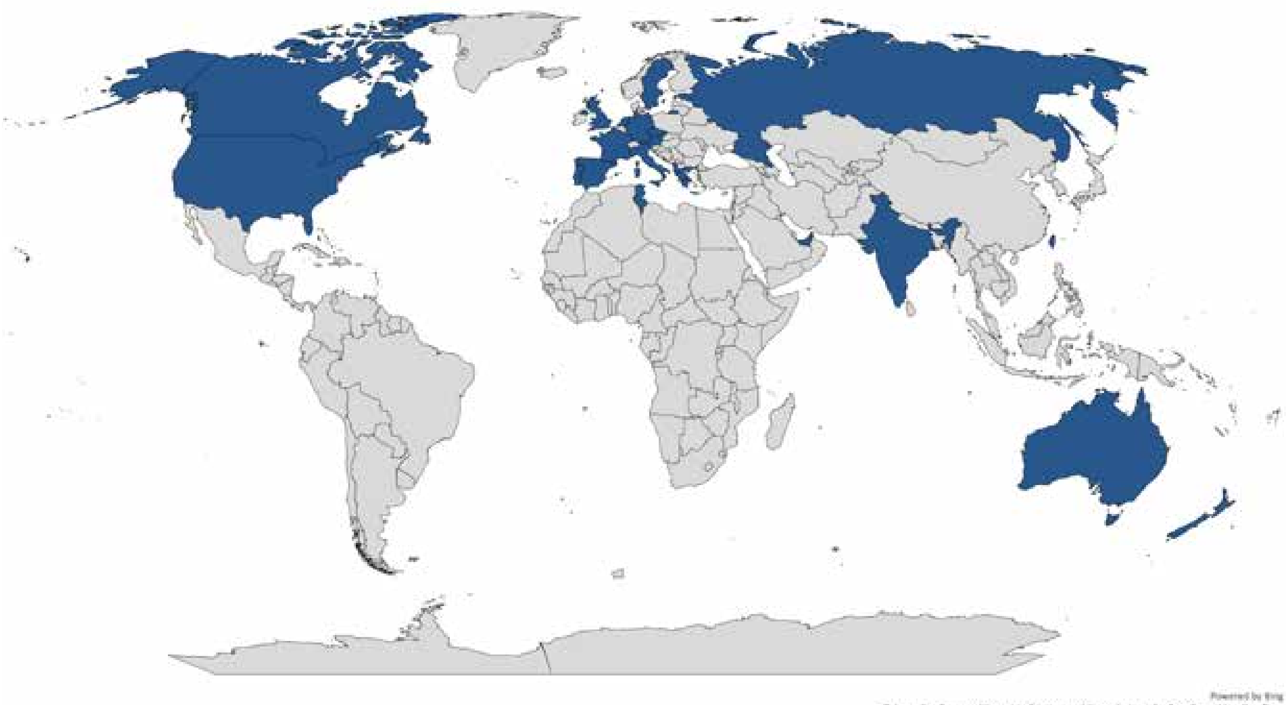

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Figure 3.2 Countries hosting the *Brassica* collections for which survey responses were received (Blue).

single event. The value of the SGSV as a location for safety duplication was understood; however, not all collection holders use this facility. Some collections reported that they prefer, or are required, to maintain duplicates at a central facility within their country. Other constraints to using the SGSV included the requirement for samples to already be duplicated elsewhere (effectively triplicated). The cost of preparing and shipping seed was seen as problematic for some smaller collections.

Distribution

The distribution of samples by collections is a prerequisite for their use in plant breeding, research and other purposes. The survey responses indicated that 24 of the 26 (92%) collections are able to distribute samples upon request, although four collection holders noted that they are subject to geographical restrictions in distribution, only being able to send out material nationally or regionally rather than to any country. Most collections (92%) require a Material Transfer Agreement (MTA) or other contractual document to be in place to fulfil seed requests. The majority of collections (73%) indicated that they use the SMTA, the agreement used for material provided by signatories to the ITPGRFA, along with other MTAs or contracts where deemed appropriate. Out of the 51,789 *Brassica* accessions reported by the 26 survey respondents, 31,257 (60%) are conserved in collections using a SMTA and therefore, are in the MLS. Some collection managers mentioned that it is not always clear when the use of the SMTA is appropriate and where another type of agreement is required, particularly when distributing wild taxa.

The survey responses indicated that, over the past 3 years, on average 7,471 cultivated accessions had been distributed per year (80% nationally, 20% internationally); however, not all respondents provided distribution data. In contrast, the responses indicated a total of 176 wild accessions were distributed over the

Table 3.2 Number of Brassica accessions duplicated at the SGSV by collection holders. *Accessions in SGSV as determined from the SGSV Seed Portal (SGSV 2022); **accessions in collections as determined from combined WIEWS/Genesys dataset (2022). *** Value is likely inaccurate due to incomplete data on the BIH039 Brassica collection in Genesys and WIEWS at the time of the data analysis.

Institute Identifier	*Brassica* accessions in SGSV*	Accessions in collection**	Estimated % safety duplicated in SGSV
DEU146/DEU271	3,837	4,349	88.2
AUS165	2,437	6,581	37.0
TWN001	1,371	1,977	69.3
NLD037	1,277	1,400	91.2
USA996	1,170	-	-
SWE054	693	962	72.0
GBR006	742	5,331	13.9
PAK001	619	3,367	18.4
USA974	262	526	49.8
RUS001	214	1,651	13.0
CAN004	195	1,898	10.3
KOR011	173	-	-
TWN006	106	-	-
CHE001	49	89	55.1
POL003	44	1,506	2.9
BIH039	32	28	114.3***
AUT001	19	27	70.4
CZE122	15	1,384	1.1
IRL029	6	129	4.7
ESP004	6	246	2.4
AUS167	4	12	33.3
LBN020	2	4	50.0
THA513	1	-	-
THA032	1	-	-
EST019	1	518	0.2
ETH013	1	17	5.9
Total	13,277	-	-

same period, probably reflecting the smaller quantities of this type of material maintained in collections and the low volume of use by requestors. Collection managers painted a picture of generally increasing or stable distribution of *Brassica* materials in the recent past (Figure 3.4). Looking to the future, much the same pattern was predicted. Currently, most of the responding collections do not charge fees either for requested seeds or to cover shipping costs (only four respondents indicated that requestors were charged fees). Ten respondents expressed concerns about having procedures in place to deal with relevant phytosanitary regulations relating to seed distribution. This was confirmed during workshop discussions, as comments were made about stricter testing requirements and delays in obtaining documentation from relevant statutory authorities.

Storage conditions

Brassica seeds are recognized as orthodox, and the recommended long-term storage conditions for such seeds are 5% (+/– 1%) moisture content by weight and a temperature of −18°C (FAO 2014). Seeds with a low moisture content are hygroscopic, and consequently will absorb atmospheric moisture very easily. If this happens during storage at temperatures of <0°C, then there will be a detrimental impact on seed longevity. Moisture-proof packaging is therefore required, and can take a variety of forms, from glass to foil laminate pouches.

The survey results indicated that 15 of the 26 respondents keep 100% of their collections under long-term storage conditions. A further five collections maintain part of their collections under long-term conditions. The stated temperatures for long-term storage ranged from −10°C to −20°C. One collection reported that they use cryopreservation for long-term storage of *Brassica* seeds, at a temperature of −180°C, however most long-term storage facilities consist of conventional cold chambers or freezers. Eight respondents indicated that their collections are held under medium-term storage conditions, with a further five collections having <100% of their germplasm stored under these conditions. Medium-term storage conditions were reported as ranging from −20°C to +10°C, the majority being around +4°C. The reported levels of humidity in medium-term storage were variable, ranging from 6% relative humidity (RH) to uncontrolled humidity. Most medium-term storage facilities are cold chambers, although some collections reported using freezers and one reported using a warehouse. One collection reported that they use short-term storage conditions, however the reported conditions were akin to medium-term storage conditions (0°C and 30% RH). The definition and interpretation of short-, medium- and long-term storage conditions therefore appeared to be somewhat variable across the survey respondents.

Maintenance of seed moisture content, particularly for successful long-term seed storage, is a key consideration, and appropriate seed packaging is essential. According to the survey responses, 22 collections pack seeds in foil pouches, and 11 of those collections also pack seeds under vacuum. Five collections reported using glass containers and one reported using plastic containers. Most collections (25 respondents, i.e. 96%) reported that they dry seeds before medium- or long-term storage, with most having access to low-temperature drying equipment or space.

Addressing collection gaps

Ideally, global collections of *Brassica* crops, as for other crops, would cover different crop types and wild species at sufficient depth (in terms of numbers of accessions) to ensure that crop genepool diversity, in terms of alleles and frequencies, is represented

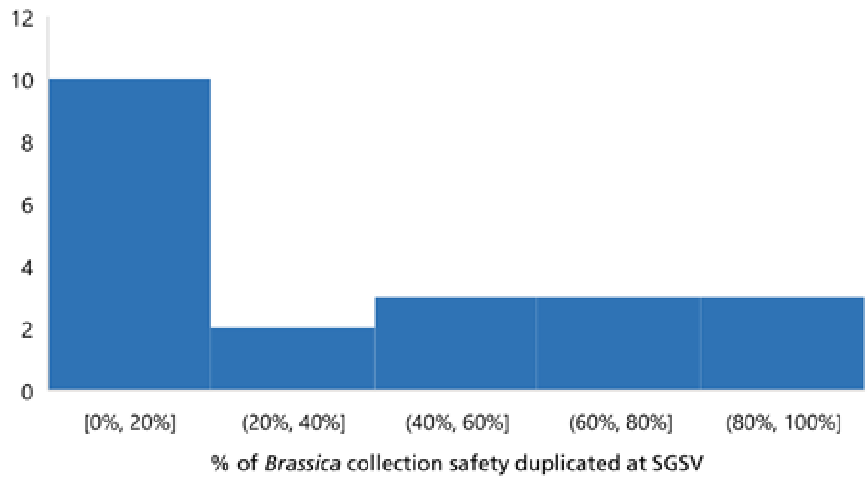

Figure 3.3 Histogram showing the distribution of the estimated percentage of Brassica collections safety duplicated at the SGSV. Estimates were binned in five categories, each with the same width and capped to 100% (n = 21).

and conserved. In fact, as with most crops, the global collections of *Brassica* crops offer in-depth coverage of some parts of the genepool more than others; this is certainly true even when considering the six major cultivated species (Table 3.3). Gaps in collections first require identification and description before activities (for example, collecting missions) are undertaken to resolve the gaps.

Gaps in collections were indicated by 18 respondents. The type of gap reported is shown in Table 3.3. Ecogeographic and genetic gaps were the most commonly identified, but gaps in the taxonomic coverage of collections were frequently identified as well. Only two respondents indicated gaps in existing CWR samples within their collection, and one respondent indicated that particular crop types were missing from their collection. Some collections reported that they have plans in place to deal with gaps; three respondents indicated that collecting activities are already planned; and eight would like to undertake such activities in the future if resources permit. Four respondents indicated no plans are in place, and a further nine gave no information on future plans. Where comments were given about the nature of gaps and plans to address them, it was clear that collection managers recognize the importance of ecogeographic coverage. Other desirable targets included the conservation of specific crop types, acquiring material with novel pest and disease resistance, and ensuring that a good representation of genetic diversity within crops from specific countries or regions is conserved.

The workshop discussions on the topic of collection gaps revealed a recognition of the importance of collections working together. It was generally seen as a waste of resources to acquire material already held in other collections that is available for distribution. Joint projects are likely to be needed, particularly to aid smaller collections to meet their goals in addressing gaps in their coverage. An additional constraint to gap filling and collection expansion are the requirements surrounding Access and Benefit Sharing (ABS). On the whole, workshop participants felt that cultivated types are better covered in collections than are CWR. This contrasts with the survey findings shown in Table 3.3 in terms of reported gaps, but not all collections that responded to the survey manage CWR within their germplasm collections, and others have a limited remit, for example, national.

Managing CWR

Brassica CWR are key components of *Brassica* genepool diversity. There is uneven coverage of different groups of CWR within global collections; wild/naturalized populations of cultivated species are generally well covered but other taxa are poorly represented. For the purposes of this strategy, consideration was given to CWR in the *Brassica* genus. Some species outside the *Brassica* genus could also be considered as CWR (for example, species in the genera *Sinapis*, *Eruca* and *Raphanus* can hybridize with *Brassica* species); however, they have not been included in this analysis. Species in these genera are crops in their own right (for example *Sinapis alba* – white mustard, *Raphanus sativus* – radish, *Eruca sativa* – rocket), so not all species in those genera can be considered as CWR.

The *Brassica* genus is polyphyletic, with closer relationships between species currently classified in different genera within major *Brassica* lineages (Warwick and Black 1991). In total, 973 CWR accessions of *Brassica* are listed in the combined WIEWS/Genesys dataset.

Table 3.3 Summary of collection gaps identified by 26 survey respondents.

Gap type	Frequency of mention by survey respondents
Ecogeographic	13 (50%)
Genetic	13 (50%)
Taxonomic	12 (46%)
CWR	2 (8%)
Crop type	1 (4%)

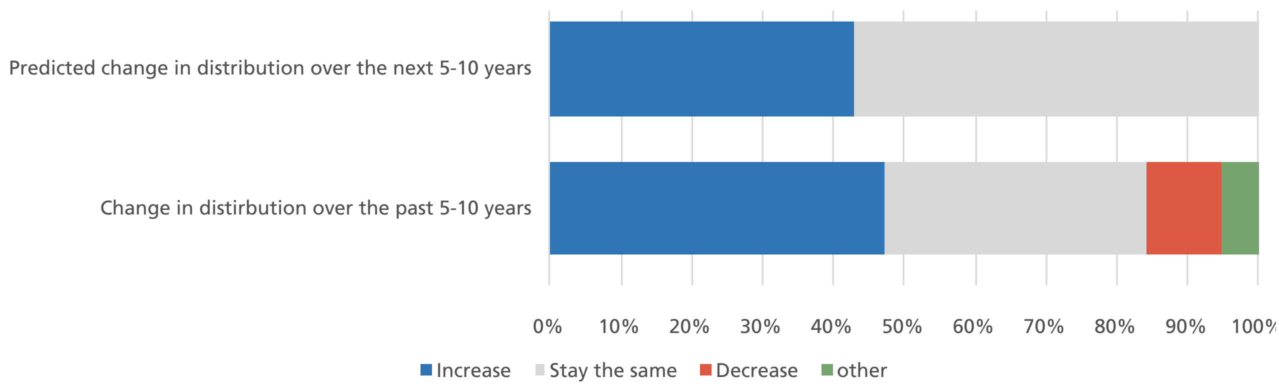

Figure 3.4 Changes in the volume of materials distributed from collections in the past 5–10 years (n = 19), and predicted change in distribution in the next 5–10 years (n = 21).

The 26 survey respondents indicated that 597 accessions of 26 species (standardized taxonomy was applied, Table 3.4) are conserved in their collections. The survey respondents were also asked about availability. Not all respondents provided this information, but those that did indicated that 293 accessions are available to requestors.

Regeneration issues were felt to be particularly relevant to *Brassica* CWR during discussions at the workshop. Some participants noted the long juvenile period of some species when grown for seed production (five years is not unusual). This may be due to environmental factors relating to the latitude and conditions at particular institutions. Nevertheless, it is potentially a significant factor in the availability of seeds of certain *Brassica* CWR species.

Some identified gaps in the *ex situ* coverage of *Brassica* CWR are *Brassica assyriaca, Brassica beytepeensis, Brassica cadmea*, *Brassica deserti, Brassica setulosa, Brassica somalensis, Brassica taurica* and *Brassica trichocarpa.* Also, *B. drepanensis* and *B. hilarionis,* classified as Endangered by the International Union for Conservation of Nature and Natural Resources (IUCN) (IUCN 2011; IUCN 2020), have a relatively low number of conserved accessions. Some species are much better covered than others (*B. cretica*, *B. fruticulosa* and *B. tournefortii* in particular). This reflects taxonomic diversity – sub-specific designations are used by collection holders, but the data in Table 3.4 are shown only at the species level. Geographical range is another factor; higher numbers of accessions may represent good sampling across the recognized range of species.

Documentation

Efficient and accurate collection management requires a suitable (fit for purpose) data management system. This can be achieved by using specific or generic database software systems. Alternatively, depending on collection size and complexity, it can be carried out adequately using a spreadsheet. However, the latter will lack certain search and aggregation functions, and this becomes more problematic with larger collections.

All but one of the collection holders responding to the survey indicated that they use software for collection management purposes. The most frequently used software is GRIN-Global (used by 10 out of 26 collections, i.e., 38%), a publicly available system developed from open-source tools. It offers not only collection data management but also a web tool for potential users to search the collection data. Other software packages used include MS Access and Excel, as well as bespoke database systems developed specifically for each collection. As indicated by the responses, data availability to potential users is generally good: 22 respondents (85%) indicated that the collection data are at least partly publicly available, and 17 (65%) further indicated that data are at least partly available and searchable online.

Nineteen respondents (73%) reported that their database system is fit for purpose. Three (12%) stated it is not, but have plans to upgrade or change the system, whilst two (8%) indicated that although the data management system is not fit for purpose, there is no plan in place for improvement.

The discussions during the workshop suggested that it is difficult for collection managers to keep up with best practice and understand what data management tools are available to them, especially for smaller collections with limited in-house information technology expertise.

3.4 Summary of current *ex situ* conservation status of *Brassica* crops and CWR

In general, *Brassica* crops are well-represented across the global collections of PGR; however, concerns and gaps do exist and require careful consideration in terms of how to address them. The coverage of crop species in particular reflects current agricultural importance, with *B. nigra* being less represented in global collections as its cultivation has not been as widespread as that of other species.

The overall picture of the conservation of *Brassica* genetic resources is also positive, at least for the collection holders who responded to the survey. Most collections are held in long- or medium-term storage, and packaged appropriately to maximize seed longevity. Regeneration was identified as a key challenge, either in terms of staff, financial or physical resources, or due to the biological nature of the materials conserved (F_1 hybrids, biennial vegetable crops compared with oilseeds, crop wild relatives adapted to different physical environments). Regeneration is also linked intrinsically to safety duplication – sufficient, high-quality seeds must be available for duplicate samples. Therefore, supporting regeneration activities, particularly for germplasm that is otherwise poorly represented across global collections, is essential to improve the conservation and availability of *Brassica* germplasm.

Collection holders indicated that they support the use of their materials through distribution – however, many mentioned budgetary constraints warranted the use of with handling, sample or shipping fees, which are passed on to users. Another issue of concern is the developing area of phytosanitary regulations and ensuring that requirements are met, now and in the future.

The importance and diversity of *Brassica* CWR were also noted, although not every collection manages this type of germplasm. Taxonomic representation is uneven across global collections, although this must be considered alongside the relationship between the cultivated and wild species concerned. The polyphyletic nature of the *Brassica* genus means that not all species fall into the primary or secondary genepool of the six crop species.

Table 3.4 *Brassica* CWR IUCN Red List category (IUCN 2011; IUCN 2020) and holdings as reported by 26 collection holders and in the combined WIEWS/Genesys dataset (2022). Taxa reported in Genesys and WIEWS have been standardized and are reported only at the species level. n/a, not applicable

Species	*In situ* status (with source)	Accessions in collection as reported in the survey	Accessions reported in WIEWS/ Genesys dataset (2022)	Accessions reported in WIEWS and Genesys and included in the MLS
B. assyriaca Mouterde	n/a	-	-	-
B. aucheri Boiss.	n/a	3	3	
B. balearica Pers.	Least Concern (IUCN 2011)	9	14	9
B. barrelieri (L.) Janka	Least Concern (IUCN 2020)	19	20	10
B. beytepeensis Yıld.	n/a	-	-	-
B. bourgeaui (Webb ex Christ) Kuntze	Threatened (National Red List 2008)	6	6	4
B. cadmea Heldr. ex O.E.Schulz	Data Deficient (IUCN 2011)	-	-	-
B. cretica Lam.	Least Concern (IUCN 2020)	95	146	12
B. deflexa Boiss.	n/a	7	10	0
B. deserti Danin & Hedge	n/a	-	-	-
B. desnottesii EmB. & Maire	Possibly Threatened (IUCN 1997)	3	4	1
B. dimorpha Coss. & Durieu	Possibly Threatened (IUCN 1997)	1	3	0
B. drepanensis (Caruel) Damanti	Endangered (IUCN 2020)	7	16	6
B. elongata Ehrh.	Least Concern (IUCN 2020)	19	23	1
B. fruticulosa Cirillo	Least Concern (IUCN 2020)	62	73	28
B. gravinae Ten.	n/a	11	12	5
B. hilarionis Post	Endangered (IUCN 2011)	2	9	1
B. incana Ten.	Data deficient (IUCN 2011)	39	84	21
B. insularis Moris	Near Threatened (IUCN 2011)	15	50	9
B. loncholoma Pomel	n/a	-	1	1
B. macrocarpa Guss.	Critically endangered (IUCN 2011)	26	27	17
B. maurorum Durieu	n/a	6	11	4
B. montana Pourr.	Least Concern (IUCN 2011)	13	68	21
B. nivalis Boiss. & Heldr.	Least Concern (IUCN 2020)	-	1	0
B. procumbens (Poir.) O. E. Schulz	n/a	-	3	0
B. oxyrrhina (Coss.) Willk.	Not Threatened (IUCN 2011)	9	12	4
B. repanda (Willd.) DC.	Least Concern (IUCN 2011)	21	41	4
B. rupestris Raf.	Near Threatened (IUCN 2011)	11	37	9
B. setulosa (Boiss. & Reut.) Coss.	n/a	-	-	-
B. somalensis Hedge & A.G.Mill.	n/a	-	-	-
B. souliei Batt.	n/a	5	7	3
B. spinescens Pomel	Threatened (IUCN 1997)	4	6	2
B. taurica (Tzvelev) Tzvelev	n/a	-	-	-
B. tournefortii Gouan	Least Concern (IUCN 2011)	171	242	55
B. trichocarpa C.Brullo, Brullo, Giusso & Ilardi	n/a	-	-	-
B. tyrrhena Giotta, Piccitto & Arrigoni	n/a	1	1	0
B. villosa Biv.	Near Threatened (IUCN 2011)	32	43	17
Total		**597**	**973**	**244**

Photo: Charlotte Allender

4 PRIORITIES FOR IMPROVING THE *EX SITU* CONSERVATION OF *BRASSICA*

Future investment and improvement plans targeting enhanced conservation of *Brassica* genetic resources around the world require careful consideration of priorities to ensure optimal benefits. The literature review, survey, and workshop discussions conducted during the development of this strategy provide a sound basis for determining priorities. These priorities will support high-quality, efficient and cost-effective conservation of *Brassica* genetic resources, ensuring their improved and ongoing availability to users in the future. *Brassica* crops are of major economic and nutritional significance on a global level. Access to genetic resources for research and breeding will help support food and nutritional security for a growing global population, and will support the development of the improved crop varieties that are needed for more sustainable farming systems.

4.1 Support for regeneration and long-term storage

The survey results and workshop discussions indicated that regeneration is very much a limiting factor, as it affects other aspects of collection management, such as distribution to users and safety duplication. Future financial assistance should be targeted at collections that are unable to support sufficient regeneration activity, prioritizing unique and important materials. Other means of achieving this objective include networking activities among genebanks, so that emergency regeneration can be provided as a service by those with the resources and facilities to do so. Such activities would also have to account for the relevant plant health laws and regulations of the countries concerned. Another option for improving regeneration capacity is to seek assistance from other organizations, such as plant breeding companies, to provide additional capacity for at-risk accessions. Some genebanks currently operate in partnership with breeding companies, which contribute toward regeneration as an 'in-kind' form of support; a notable example is the Centre for Genetic Resources in The Netherlands. Improving the regeneration capacity will ensure ongoing availability of materials to users, as well as long-term conservation. As noted by the workshop participants, safety duplication is linked to regeneration activities, so that that duplicates consist of high-quality, highly viable seeds. Ensuring collections can carry out sufficient regeneration, targeting unique and valuable materials, will support this essential component of collection management. Investment in infrastructure to allow collections to use long-term storage conditions where appropriate will reduce the frequency of regeneration required, further improving conservation efficiency and effectiveness.

4.2 Identification of unique materials for priority conservation

Although more than 7.4 million accessions of all crops/species are recorded in collections of PGR around the world, only an estimated 30% of these are unique, with duplicate samples being maintained within and especially among collections (FAO 2010). *Brassica* genetic resources are also likely duplicated across collections; therefore, it is important to identify unique materials to better target limited resources for conservation. Such an exercise would clarify gaps in the global collection and enable collecting and gap-filling activities to be planned.

However, the identification of duplicate materials is far from straightforward. It is likely that this information will only be gained through collective activities, utilizing both existing collection (passport) information and genetic/genomic approaches, as well as phenotyping where necessary. This activity is likely beyond the scope of individual collections, and will require a joint approach, probably through a program of activities carried out in parallel with routine collection maintenance. This work will need a collaborative approach involving collection managers, experts in genotyping and bioinformatics, and a coordinating project secretariat. It will be necessary to identify the most robust, cost-effective approaches and consult with those that manage other crops (such as cereals), where collections have already undergone characterization by genotyping or sequencing. Determining the threshold for uniqueness is a key issue, along with practical aspects of suitable sampling strategies to compare diversity among heterogeneous populations. Because brassicas are outcrossing species — the threshold level of inter-accession genetic diversity compared with intra-accession genetic diversity that would indicate accessions are different is not always clear.

Characterization and evaluation activities also aid the identification of significant accessions for conservation. Ideally, this could be carried out during regeneration activities to bring added value; however, this is not always possible and additional resources are required for these activities. The identification and use of a set of minimum descriptors would allow for comparison among collections. Various descriptor lists are used, but not all descriptors on each list are scored every time. Therefore, to allow comparisons among datasets, it would be helpful to agree on a key minimum set of descriptors that are always scored.

Another issue is the taxonomic identification of materials in PGR collections. Not all collections have access to taxonomic expertise, and errors can be made or perpetuated. The analysis of accessions' passport data recorded in online databases after standardizing[1] taxa, as described above, is one way to address this issue, although it is not clear how effective it will be given the polyphyletic nature of the *Brassica* genus.

4.3 Documentation – making information available to users and managers

The survey responses were encouraging – most collections already have, or are planning to install, software capable of managing their collections and making relevant data available to users where appropriate. GRIN-Global is one tool available to all collections. However, discussions in the workshop revealed a gap between the requirements of some collections, particularly smaller ones, and the technical capability to install and manage such packages. There is a need to be able to share experiences with peers and exchange information on best practices. This could be achieved as part of dissemination activities undertaken by a global *Brassica* PGR network (see point 5), but also by co-opting other groups and organizations with relevant interests, such as the relevant European Co-operative Programme on Plant Genetic Resources (ECPGR) working group (see ECPGR: ECPGR Documentation and Information Working Group). It is essential that support is continued for the further development of GRIN-Global, including direct support to users provided *via* the helpdesk, and training to assist organizations to install the system and migrate their data into it. Obviously, supporting and improving data management in collections of PGR has benefits for the conservation and use of all crops. Therefore, activities undertaken to improve data management will have much wider benefits beyond *Brassica* conservation.

4.4 Crop wild relatives

The CWR are an invaluable source of alleles and traits for plant breeding programs. They are also essential for research on plant and crop biology, evolution and domestication. A gap analysis of global collections for *Brassica* CWR is essential: the incomplete information gained from the survey suggested that availability to users may be an issue with this type of germplasm in particular. Discussions at the workshop indicated that some collection managers have problems with regenerating some taxa due to extended juvenile periods

1 Genesys also now includes an automatically generated standardized taxon field.

before flowering. Understanding which accessions are available for distribution at a global level, and which require regeneration or re-collection, is an essential step to ensure optimal conservation of these species. This would include an assessment of intra-species diversity facilitated by genetic/genomic analysis to ensure that sufficient populations are sampled to conserve species genetic diversity. A gap analysis is being undertaken for the wider Brassicaceae group of wild relatives, and will provide the starting point for this work (Castillo-Lorenzo et al. 2022). This will need to be extended in terms of assessment of the accessions currently available for distribution through consultation with collection managers.

4.5 A global *Brassica* PGR conservation network

Networking among collections would allow for sharing of best practices, and the provision of advice and support on a sustained or *ad hoc* basis. A network of *Brassica* collection holders would facilitate access to crop- and taxon-specific expertise. Broadening the network beyond collection holders to include potential providers of in-kind support would be a means of linking organizations for the best conservation outcomes. A regional example of this kind of network is the *Brassica* Working Group of the ECPGR. In this group representing 34 countries, 75 members have a range of roles, from collection curators, to researchers, plant breeders and policy experts. This group provides a forum for technical queries, project participation and best-practice dissemination. A global network would offer wider opportunities for cooperation and improvements to conservation effectiveness and efficiency. This network could be formed by inviting collection holders to join the existing European network. Such a network would ideally include a range of other commercial and academic organizations with interests in *Brassica* species. These organizations may be able to provide expertise or resources to address regeneration, as well as genetic or phenotypic characterization and other issues. The network may also be able to address and interact with phytosanitary authorities to support the use of collections while managing risk appropriately. A small amount of funding for a secretariat would be required to ensure good communication.


Photo: Charlotte Allender

ACRONYMS AND ABBREVIATIONS

BMEL	Federal Ministry of Food and Agriculture, Germany
CWR	Crop wild relatives
ECPGR	European Co-operative Programme on Plant Genetic Resources
FAO	United Nations Food and Agriculture Organization
Genesys-PGR	Genesys-Plant Genetic Resources
GRIN-Global	Germplasm Resource Information System - Global
IPK	Leibniz Institute of Plant Genetics and Crop Plant Research
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
IUCN	International Union for Conservation of Nature and Natural Resources
MTA	Material transfer agreement
MYA	Million years ago
PGR	Plant genetic resources
RH	Relative humidity
SMTA	Standard material transfer agreement
SNP	Single nucleotide polymorphism
WIEWS	World Information and Early Warning System
YBP	Years before present

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APPENDICES

Appendix 1. *Brassica* genetic resources stakeholders survey

Brassica Conservation Strategy

Introduction

The Global Crop Diversity Trust (the Crop Trust) is an international non-profit organization, whose mission is to conserve and make available crop genetic diversity in perpetuity, thus ensuring global food security. As part of this mission, the Crop Trust has supported the development of 28 crop-specific conservation strategies to date, available at www.croptrust.org/our-work/supporting-crop-conservation/conservation-strategies/. These strategies comprehensively assess the status of crop conservation globally, with a particular emphasis on ex situ collections, and identify key priority actions needed to preserve crop diversity effectively and efficiently for the future.

New strategies are currently under development for additional crops, including brassicas (*Brassica* spp.). The *Brassica* Global Conservation Strategy is being coordinated by an independent consultant (Dr. Charlotte Allender) commissioned by the Crop Trust. The strategy will critically depend on input and feedback from *Brassica* specialists and collection curators. As such, the following questionnaire has been designed to connect with collection curators worldwide, in order to make a baseline assessment of the current conservation status of *Brassica* genetic resources.

We would like to invite you to become a partner in this global initiative by completing the brassica questionnaire: As the curator and/or manager of a brassica ex situ collection, the information you provide will be vital to our global assessment. The collection data we receive via the questionnaire will be used to address not only the extent of *Brassica* genetic diversity conserved worldwide, but also how securely it is conserved and if there are any collection gaps. The questionnaire contains 81 questions and should take approximately 60-90 minutes to complete.

Please complete the survey at your earliest convenience, but no later than Monday 28th February, 2022 and return by email reply. Survey responses, questions/concerns on how to complete the questionnaire, or feedback on the strategy itself, can be directed to Charlotte Allender (charlotte.allender@warwick.ac.uk).

Thank-you in advance for your participation in this important initiative!

Note: One question (Q12) needs to be answered separately, please see the additional file for Q12 sent along with the survey email (if applicable for your collection).

Data Protection

The data you supply will be used to develop a global ex situ brassica conservation strategy. It will be held securely by the University of Warwick and will be shared with The Crop Trust (headquartered in Germany) for the same purpose. Your responses to the survey will be aggregated and anonymized in the final published document. Your personal details will not be shared with third parties, however with your permission we would like to include your name, institutional details and contact email address in the final *Brassica* strategy document.

Any questions, requests, or complaints you may have regarding the processing of your personal data can be sent to us by email at dataprotection@croptrust.org or by post to Platz der Vereinten Nationen 7, 53113 Bonn, Germany.

Please check the appropriate boxes below:

☐ I confirm that I have read and understand the data protection rules

☐ I give consent to the processing of my personal data the purposes of the research (Optional)

☐ I give consent to the processing of my personal data by including my name, institutional details, and contact email address in the final *Brassica* strategy document (Optional)

ORGANIZATION INFORMATION

1. Organization holding/maintaining the *Brassica* collection:

Name of Organization	
Address	
City/Town	
State/Province	
ZIP/Postal Code	
Country	
Website	

2. Curator in charge of the *Brassica* collection:

Name	
Job Title	
Telephone	
Email	

3. Name of respondent to this questionnaire (if not as above):

Name	
Function/Job Title	
Telephone	
Email	

4. Additional key contact person for the *Brassica* collection (if applicable):

Name	
Function/Job Title	
Telephone	
Email	

5. Is the organization in charge of the *Brassica* collection the legal owner of the collection? (Y/N) If not, who is the owner?

6. Describe the organization (select one):

Governmental organization	
University	
Private organization	
NGO or charity	
Other (please specify)	

7. Does the genebank or collection operate under a national conservation strategy, policy, or plan? (Y/N) If yes, please specify.

8. Who has the most influence on genebank priorities (e.g., objectives, species focus, activities)? (Select one).

The curator(s) of the collection	
The organization/department management	
A governing committee	
A stakeholder committee	
Other (please specify)	

THE *BRASSICA* COLLECTION

9. Basic information on the *Brassica* collection:

Year of establishment	
Total number of *Brassica* accessions (today)	
Total number of *Brassica* species (today)	
Total number of *Brassica* accessions currently available for distribution	

10. The main objectives of the collection include (select all that apply):

Long-term conservation	
Working collection for public breeding/research program	
Working collection for private breeding/research program	
Academic or educational use	
Reference collection	
Other (please specify)	

11. For the cultivated species, *Brassica*, indicate the number of accessions by germplasm type:

	B. oleracea	***B. rapa***	***B. nigra***	***B. carinata***	***B. juncea***	***B. napus***
Total number of accessions						
Landraces						
Obsolete/traditional cultivars						
Advanced/improved cultivars						
Breeding/research materials						
Specialist genetic stocks						
Wild or weedy populations						
Unknown						
Other						

12. If you hold accessions of other *Brassica* species, please complete the additional document "*Brassica* Crop Wild Relatives (Q12)" to detail your collection holdings by species. Please return via email with the questionnaire.

13. To what extent do you consider the *Brassica* accessions in your collection to be unique and not duplicated elsewhere (excluding safety duplication)?

	100% unique	**More than 50% unique**	**Less than 50% unique**	**Fully duplicated elsewhere**
Cultivated *Brassica*				
Wild *Brassica*				
Crop wild relatives (i.e., other *Brassica* spp.)				

14. Across the entire *Brassica* collection, how many countries of origin are represented?

15. Describe the geographic origins of the collection by indicating the proportion (%) of cultivated *Brassica* accessions that were collected/obtained (total should sum to 100%):

Nationally	
Regionally (excluding own country)	
Internationally (excluding own region)	
Unknown	

16. Are there any known or perceived gaps in your *Brassica* collection (check all that apply):

Genetic gaps
Taxonomic gaps
Ecogeographic gaps
Other gaps

Please briefly describe any gaps.

17. If there are collection gaps, as indicated in Q17, how and when do you plan to fill these gaps, if at all?

18. To what extent do you consider duplication within your *Brassica* collection to be a problem?

No duplication within the collection
Low amounts of duplication (< 10%)
Moderate amounts of duplication (10-30%)
Duplication is extensive (> 30%)

Do you have plans to conduct collection rationalization to eliminate duplicates?

19. To characterize collection dynamics, indicate the number of *Brassica* accessions that have been:

Acquired in the past 10 years?
Lost from the collection in the past 10 years?
Removed as they were identified as duplicates?

EX SITU CONSERVATION FACILITIES

20. Indicate the proportion (%) of *Brassica* accessions that are maintained under the following conditions:

(Note: if accessions are maintained under multiple conditions, total may exceed 100%.)

Short-term storage
Medium-term storage
Long-term storage

For the following questions in this section (Q24-Q30), you need answer only for the storage conditions applicable for your collection.

24-26. Please describe the storage facilities (check all that apply):

	Short-term storage (Q24)	Medium-term storage (Q25)	Long-term storage (Q26)
Type of facility (warehouse, cold chamber, freezer, etc.)			
Conservation method (seed, *in vitro*, etc.)			
Temperature (°C)			
Relative humidity (%)			

27. The storage facilities may be best understood as (check all that apply):

	Short-term storage	Medium-term storage	Long-term storage
Cold chambers			
Individual freezers			
Air-conditioned rooms			
Air-conditioned rooms with dehumidifier			
Not climate-controlled			

28. The temperature and relative humidity are monitored by (check all that apply):

	Short-term storage	Medium-term storage	Long-term storage
Internal temperature monitors			
Internal relative humidity monitors			
External sounding alarms			
Automated monitoring system			
Daily visit by genebank or security staff			
Others (please specify)			

29. What type of packaging is used for seed conservation (check all that apply):?

	Short-term storage	Medium-term storage	Long-term storage
Sealed aluminum packs			
Sealed, vacuum-packed aluminum packs			
Plastic containers			
Glass containers			
Paper envelopes or bags			
Cloth bags			
Other (please specify)			

30. Are seeds dried before storage?

	Short-term storage	Medium-term storage	Long-term storage
Yes			
No			
N/A			

31. Do the genebank facilities include (check all that apply):

Separate work areas for 'dirty' and 'clean' seed handling procedures
Separate work areas for seed packaging for storage and distribution
Dedicated laboratory and trained staff for seed viability testing
Dedicated laboratory and trained staff for seed health testing
Low temperature seed dryer
Suitable field sites for regeneration and multiplication
Greenhouse/glasshouse facilities for regeneration and multiplication
Other (please specify)

GERMPLASM MANAGEMENT

32. Have you established a genebank management system or written procedures/protocols for:

	Yes	No	N/A
Acquisition			
Conservation (storage, maintenance, etc.)			
Regeneration			
Characterization			
Distribution			
Safety duplication			
Information management			
Germplasm health (viability testing, phytosanitary, etc.)			

33. The genebank uses written procedures and protocols from (check all that apply):

No written procedures or protocols
Hanson 1985. Practical Manuals for Genebanks No. 1: Procedures for Handling Seeds in Genebanks. IBPGR.
FAO/IPGRI 1994. Genebank Standards.
Rao et al. 2006. Handbooks for Genebanks No. 8: Manual of Seed Handling in Genebanks. Bioversity International.
Organization's own "Operational Genebank Manual"
Written and verified Standard Operating Procedures (SOPs) for key processes
A Quality Management System (QMS)
Other (please specify)

34. Please describe your quality control activities for conserved seeds:

	Frequency	Protocols/Methods
Germination testing		
Viability testing		
Health testing		

35. What are the parameters used to determine regeneration requirements and to maintain the viability of your *Brassica* collection?

36. What proportion (%) of your *Brassica* collection requires urgent regeneration (apart from the normal routine regeneration)?

Cultivated *Brassica*	
Wild *Brassica*	
Crop wild relatives (other *Brassica* spp.)	

37. Is the collection affected by diseases that may restrict germplasm distribution? (Y/N) If yes, please list the relevant diseases and describe the extent.

SAFETY DUPLICATION

38. Are accessions safety duplicated at another genebank?

Yes
Partly
No
Don't know

If you answered Yes or Partly, please complete the following three questions (Q39-Q41). If No, skip these questions.

39. Please indicate the proportion (%) of *Brassica* accessions safety duplicated by arrangement:

(Note: if accessions are safety duplicated at more than one location, total may exceed 100%.)

Svalbard	
Black box outside country	
Integrated in another collection outside country	
Black box within country	
Integrated in another collection within country	
Other	

40. Please list the institution(s) where your germplasm is safety duplicated.

41. Do all safety duplication sites have formal agreements to establish terms and obligations? (Y/N)

42. Are there constraints to duplicating the collection outside your country? (Y/N) If yes, please specify.

43. Are *Brassica* accessions from other collections safety duplicated at your facilities? (Y/N) If yes, please provide the name(s) of the original collection holder(s) and the number of accessions?

DOCUMENTATION AND INFORMATION MANAGEMENT

44. Do you use a searchable electronic platform (computerized database) for storing and retrieving accession-level data? (Y/N) If yes, what software is used?

45. The accession-level information is (check all that apply):

Public
Private
Available by written catalogue or by contacting the curator
Available & searchable online within the institute
Available & searchable online outside the institute

46. If the accession-level information is publicly available on the internet, please provide the URL (web address).

47. The accession-level database provides the following information (check all that apply):

Passport
Taxonomy
Characterization
Evaluation
Genotypes
Images
Distribution
Other (please specify)

48. What proportion (%) of the Brassica collection has:

Passport data
Geo-referencing data

49. If you use a computerized database to manage the collection and share accession data, is it adequate to meet the needs of both the genebank and users? (Y/N) If inadequate, are there plans to upgrade or improve this system?

50. Are the accession-level data describing your collection available in other, external databases?

	Yes	Partly	No	If Yes/Partly, specify the database(s):
National				
Regional				
International				

CHARACTERIZATION AND EVALUATION

51-52. What proportion (%) of cultivated and wild accessions have:

	Cultivated accessions (Q51)	Wild accessions (Q52)
Agro-morphological (phenotypic) characterization data		
Genotypic characterization data (molecular markers, etc.)		
Abiotic stress tolerance data		
Biotic stress tolerance data		

53. If abiotic/biotic stresses have been at least partially assessed, please list the specific stresses that have been evaluated.

54. Indicate the descriptors used for agro-morphological characterization:

FAO/IPGRI multi-crop passport descriptors (MCPD 2015)
IBPGR brassica descriptors (1985)
Institute-specific descriptors
UPOV descriptors
USDA brassica descriptors
Other (please specify)

55. Can you describe any core collections or other trait-specific subsets of accessions that have been established for the *Brassica* collection?

DISTRIBUTION

56. Do you distribute accessions from your *Brassica* collection? (Y/N) If no, why not?

If you answered Yes to the previous question (Q56), please complete the remaining questions in this section (Q57-Q69). If you answered No, you may skip to the next section.

57. Are you able to distribute:

Only to users in your own country
Only to users in certain countries (i.e., regionally)
Internationally, to any country

58. What best describes the conditions that must be met for distribution:

Freely distributed without terms or conditions
Institutional material transfer agreement (MTA) or other bi-lateral agreement
The Nagoya Protocol for the CBD
The International Treaty on PGR for Food and Agriculture (ITPGRFA)
Other (please specify)

59. For the following categories, how many accessions are typically distributed annually (average of last 3 years)? Answer where applicable. (Note: wild materials include wild *Brassica* as well as other *Brassica* species.)

	Nationally	Internationally
Cultivated accessions		
Wild accessions		

60. How have your distributions changed over the last 5-10 years?

Increased
Stayed the same
Decreased

61. How do you expect your distributions to change over the next 5-10 years?

Increase
Stay the same
Decrease

62. Are there factors that currently limit, or may limit in future, the distribution and use of materials maintained in your collection? Please detail in space below.

63. Do you keep records of the germplasm distributed? (Y/N)

64. Of your annual distributions, what kind of users have received germplasm from your collection? Please estimate the proportion (%) of total distribution over the last 5 years (total should sum to 100%):

Farmers or farmer organizations
Governmental departments
Other genebank curators
Academic researchers and students (universities)
Research institutes
Breeding programs: public sector
Breeding programs: private sector
Non-governmental organizations (NGOs)
Other

65. Do you charge fees for the following services? (Y/N)

The cost of accessions
The cost of shipping

66. Do you have any concerns over the procedures in place for: (Y/N)

Phytosanitary certification
Packaging
Shipping

67. Do you routinely solicit feedback from recipients on the following aspects (check all that apply):

Timeliness of the distribution
Helpfulness of genebank staff in selection of accessions
Quality of samples sent
Quality and usefulness of accession-level information received
Usefulness of the accessions received
Reports/publications resulting from the evaluation or use of the accessions received
Resultant characterization/evaluation data sets
Varietal releases
Other (please specify)

68. How do germplasm users influence the management of the collection (check all that apply)?

Through feedback on available materials/distributions
Through formal consultations
Through participation in the governing body of the genebank
Other (please specify)

69. How are the accessions available for distribution publicized?

LONG-TERM COLLECTION VULNERABILITY

70. Does your organization provide most or all of the recurrent costs for maintaining the *Brassica* collection? (Y/N) If not, who are your other significant funders?

71. How has the budget for conservation of the collection changed over the last 5 years?

Increased
Stable
Decreased

If it has decreased, please describe any other funds sourced to make up the shortfall?

72. Do you have adequate staff, training, and expertise for: (Y/N)

	Number of staff	Level of expertise	Training
Managing routine annual genebank operations			
Meeting annual distribution requests			
Addressing the needs of users for accession-level information			

73. Has there been a formal risk assessment performed and management plan developed for the genebank? (Y/N) If yes, how recently?

74. What do you consider to be the 3 most important vulnerabilities or threats to the *Brassica* collection?

1:
2:
3:

75. What are the primary disease/pathogen or pest concerns for:

Seed storage
Distribution
Regeneration/multiplication

76. How do you predict the size of the collection to change in the next 10 years?

Stay approximately the same size
Limited expansion (5-10%)
Substantial increase (>10%)
Decrease owing to collection rationalization
Decrease due to lack of funding/facilities

77. Please indicate the current and expected situation of your *Brassica* collection with respect to the following risk factors, where 1 = excellent, 2 = adequate, 3 = insufficient, N/A = not applicable:

	Current situation	Expected situation (2027 onwards)
Funding for routine operations/maintenance		
Retention of trained staff		
Interest for PGR conservation by donors		
Genetic variability in the collections needed by users/ breeders		
Access to germplasm information (passport data, etc.)		
Feedback from users		
Use by breeders/researchers		

NETWORKS AND PARTNERSHIPS

78. Does your genebank collaborate with other collection holders? If yes, please describe the form of your collaborations (check all that apply):

	Collection	Repatriation	Research	Safety duplication	Training	Other
Other national ex situ collection holders						
Other regional or international ex situ collection holders						
In situ conservation sites						
On farm conservation sites						
Community seedbanks						
Protected sites for wild relatives						
Other (please specify)						

79. Do you collaborate with an in situ conservation programme? (Y/N) If yes (or planned for future), please describe.

80. Do you participate (or have you participated in the last 10 years) in a plant genetic resource network (including germplasm holders and/or users)? (Y/N) If yes, please describe the network & provide a URL if applicable.

FINAL CONSIDERATIONS

81. Please add any further comments you may have in regard to your *Brassica* collection and/or this questionnaire. Recommendations for the brassica conservation strategy are also welcome.

Thank-you for your participation!

Any questions about this survey or the Global Strategy may be directed to:
Dr Charlotte Allender
charlotte.allender@warwick.ac.uk

Appendix 2. Stakeholders’ meetings participants

Brassica Global Conservation Strategy: Report from workshops

Workshop dates 23 and 24 June 2022

Chair

Charlotte Allender, Consultant to the Crop Trust

Attendees – 23 June 2022

Laura Marek
USDA-ARS Plant Introduction Research Unit, Ames, IA
1305 State Ave
Ames, IA 50014 USA

Parthenopi Ralli
Greek Gene Bank,
Hellenic Agricultural Organisation-Dimitra
Institute of Plant Breeding & Genetic Resources
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Humberto Nóbrega
Banco de Germoplasma – Universidade da Madeira
Campus da Penteada
Funchal
Madeira 9020-105 Portugal

Attendees – 24 June 2022

Catherine Cook
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Catrina Fenton
Garden Organic (Heritage Seed Library)
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Santa Cruz de Tenerife 38400 Spain

Najla Mezghani
National Gene Bank of Tunisia (NGBT)
Boulevard Leader Yasser Arafat
Charguia 1
Tunis 1080 Tunisia

Agenda for Workshop on Global Conservation Strategy for *Brassica* Crops

23 and 24 June 2022

To be held online *via* Microsoft Teams

AGENDA

1. Introductions – project and participants
2. Workshop goals
3. Summary of survey responses
4. Discussion of priorities/issues to be addressed in the global conservation strategy document
5. Open questions/further discussion

Topic areas in strategy document: identification of issues and recommendations for solutions

- Gaps in existing collections
- Documentation and information
- Distribution
- Safety Duplication
- Regeneration
- Seed storage/seed health
- Characterization/evaluation data
- Genotyping and sequencing data
- Brief introductions were given by those present.

1. Charlotte Allender outlined the goals of the workshop: to present key results from the survey, to clarify the purpose of the crop strategy documents and to seek input from the *Brassica* genetic resources community regarding priorities and recommendations to be included and discussed in the strategy document.
2. Major results from the survey were presented, highlighting key themes of responses. These can be seen on the workshop slides, available as a separate document.
3. Discussion of priorities/recommendations. The key topics listed were considered by those present in terms of reflections on their own current practice and what should be recommended for the future to improve the conservation status of global *Brassica* collections. Comments and questions from both workshops have been amalgamated into a

Discussion topics

Gaps in existing collections

- It is difficult to expand collections, particularly with ABS regulations and requirements.
- It is important to identify unique and important material across collections so that efforts aren't wasted on recollecting material held elsewhere (joint projects are needed, particularly supporting smaller collections who may not have the resources to undertake this exercise alone).
- Gaps are likely to be mostly in the *Brassica* CWR – most cultivated material is reasonably covered.
- Survey respondents indicated a desire for collection activities, but only a few.
- One collection will take a different approach to identifying gaps and use genotyping/sequencing to analyze genepool diversity and identify materials that could enhance diversity representation overall.

Documentation and Information

- Only one collection reported having no database. The majority of collections used GRIN Global, with Microsoft Access and bespoke SQL/Oracle options also being used.
- It was suggested that a means to share best practice and allow collection managers to find out about potential options would be helpful, particularly at the point at which new data management solutions are being considered.

Distribution

- Constraints discussed regarding distribution of germplasm ranged from confusion over Nagoya requirements (especially regarding wild species), problems with obtaining the necessary phytosanitary documentation and obtaining government level permission to distribute from collections where this is required.
- Possible solutions included use of the SMTA even for non-Annex 1 material to streamline practice. It might also be possible for larger collections to take in valuable material to their collections and assist with distribution.

Safety Duplication

- Safety duplication is regarded as an essential component of good collection management. Most collections were at least partly duplicated, and duplication was linked in several cases to regeneration. (Samples are sent for safety duplication when accessions are regenerated to avoid old/less viable seeds being used as a duplicate.)
- Some collections were backed up in national facilities, others internationally.
- The requirement for triplicate samples by the SGSV was seen as a constraint, as was the preparation and shipping of samples for smaller collections.
- One collection backed up material produced at each growing cycle, and this allowed them to check back to identify the source of any errors noted.

Regeneration

- Regeneration was identified as a key constraint to distribution and a factor in the long-term vulnerability of *Brassica* collections in the survey.
- Issues reported included capacity for regeneration with adequate isolation of outcrossing *Brassica* accessions – for example, many collections have fixed numbers of isolation cages, which cannot be easily expanded. Genetic integrity/erosion was identified as a vulnerability by some collection managers in the survey.
- Field isolation facilities are vulnerable to storm damage.
- Staff resources to handle regeneration was a constraining factor in some collections, sometimes requiring that fewer isolation facilities are used than would otherwise be the case.
- One collection reported that as capacity was constrained, a small sample of plants was grown up to check homogeneity and morphology of each material before it underwent a regeneration cycle – to avoid wasting effort in propagating incorrect or contaminated materials.
- Collaboration with the private sector can increase regeneration capacity – usually carried out as an 'in kind' contribution to collection management. This is much appreciated as it increases the capacity, but collection managers lose direct control of the material and regeneration conditions.
- New modern varieties are F_1 hybrids and the crossing controls (restorer lines, etc.) are not available. Parental inbred lines are also unavailable. Two collections reported that they maintain F_1 hybrid accessions by producing an F_2 population where possible. Where this is not possible, seeds will remain in the collection for as long as they remain viable but cannot be propagated further.
- Differences in the ease of regeneration among accessions were noted, impacted by the local environment/latitude of the collection and the regeneration location. Many brassicas require vernalization, which can be hard to manage. Oilseed types are much easier to manage than some of the vegetable forms, where attaining reproductive maturity can be challenging.
- *Brassica* CWR can be hard to manage in terms of regeneration – they can take up to 4–5 years to reach flowering, and only a few plants flower per growing season in some cases. This may be due to temperature/daylength combinations and light quality within glasshouses.

Seed storage/seed health

- Only one collection reported that it had no medium- or long-term storage; in general, storage conditions appeared to be acceptable.
- Regarding monitoring of seed health, it was noted that genetic differences among accessions mean that seed-lot viability differs, even among accessions regenerated in the same environment at the same time. Therefore, testing all accessions is important to avoid missing this variation. Another suggestion was to test at shorter frequencies as seeds age to adequately capture the relatively sharp drop-off in viability that occurs towards the end of the seeds' lifespan.

Characterization – including genotyping and sequencing

- Characterization was considered as a valuable but constrained activity according to the survey responses. The workshop participants discussed the potential routine use of sequencing in collection management and characterization.
- Most *Brassica* accessions represent variable populations rather than genetically homogenous entities – when sequencing/genotyping, how do the methods used account for this? A single sample may not be representative, with cost implications for sampling strategies. An alternative is to bulk material sampled from a number of individuals.
- The experience of the IPK in sequencing their entire barley collection was discussed — even for a self-pollinating species, some diversity was present in all accessions so it was difficult to ascertain what level of difference should be counted as 'unique.' The degree of genetic difference often did not correlate with phenotypic variation in the field. Care is therefore needed before making decisions based on these types of datasets.

Appendix 3. 20 largest collections of the six major cultivated *Brassica* species

Tables providing details of the 20 largest collections of the six major cultivated *Brassica* species, including FAO institute code, full name, and number of reported accessions – data sources: Online databases (Genesys and FAO/WIEWS) and survey (survey of *Brassica* collection holders 2022).

Table 1. *Brassica nigra*

		Number of ***B. nigra*** accessions	
Institute Code	**Full name of Institute**	**Online databases**	**Survey 2022**
AUS165	Australian Grains Genebank, Department of Economic Development Jobs Transport and Resources	225	183
DEU271	External Branch North of the Department Genebank, IPK, Oil Plants and Fodder Crops in Malchow	128	128
USA020	North Central Regional Plant Introduction Station, USDA-ARS, NCRPIS	99	99
IND001	National Bureau of Plant Genetic Resources	69	72
PAK001	Plant Genetic Resources Program	70	
CAN004	Plant Gene Resources of Canada, Saskatoon Research and Development Centre	25	57
ETH085	Ethiopian Biodiversity Institute	52	
RUS001	N.I. Vavilov Research Institute of Plant Industry	47	48
BGR001	Institute for Plant Genetic Resources 'K.Malkov'	32	
CZE122	Gene bank	28	
JPN183	NARO Genebank	28	
GBR006	Warwick Genetic Resources Unit	2	24
ESP003	Comunidad de Madrid. Universidad Politécnica de Madrid. Escuela Técnica Superior de Ingenieros Agrónomos. Banco de Germoplasma	23	
GBR004	Millennium Seed Bank Project, Seed Conservation Department, Royal Botanic Gardens, Kew, Wakehurst Place	23	23
ISR002	Israel Gene Bank for Agricultural Crops, Agricultural Research Organisation, Volcani Center	23	
NLD037	Centre for Genetic Resources, the Netherlands	23	23
ITA331	Facolta di Agraria, Università degli Studi di Catania	4	22
UKR013	Ivano-Frankivs'k Institute of Agroindustrial Production	21	
NZL001	Margot Forde Forage Germplasm Centre, AgResearch Ltd	5	15
HUN003	Institute for Agrobotany	14	

Table 2. *Brassica oleracea*

		Number of ***B. oleracea*** accessions	
Institute Code	**Full name of institute**	**Online databases**	**Survey 2022**
GBR006	Warwick Genetic Resources Unit	3,994	4,276
RUS001	VIR		2,472
USA003	Northeast Regional Plant Introduction Station, Plant Genetic Resources Unit, USDA-ARS, New York State Agricultural Experiment Station, Cornell University	1,595	
DEU146	Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research	1,301	1,534
FRA010	Institut de Génétique Environnement et Protection des Plantes, Plant Biology and Breeding, INRA Ploudaniel	767	892
ESP027	Gobierno de Aragón. Centro de Investigación y Tecnología Agroalimentaria. Banco de Germoplasma de Hortícolas	120	834
PRT001	Portuguese Bank of Plant Germplasm	741	
BGR001	Institute for Plant Genetic Resources 'K.Malkov'	736	
JPN183	NARO Genebank	679	
NLD037	Centre for Genetic Resources, the Netherlands	644	644

		Number of *B. oleracea* accessions	
Institute Code	**Full name of institute**	**Online databases**	**Survey 2022**
POL003	Plant Breeding and Acclimatization Institute	506	
IND001	National Bureau of Plant Genetic Resources	484	1
BGD206	Lal Teer Seed Limited	481	
AUS165	Australian Grains Genebank, Department of Economic Development Jobs Transport and Resources	461	427
SWE054	Nordic Genetic Resource Center	380	454
USA974	Seed Savers Exchange	454	
CZE122	Gene bank	271	440
ITA331	Facolta di Agraria, Università degli Studi di Catania	209	411
MNG030	Plant Science Agricultural Research and Training Institute	406	
ESP026	Generalidad Valenciana. Universidad Politècnica de Valencia. Escuela Técnica Superior de Ingenieros Agrónomos. Banco de Germoplasma	323	

Table 3. *Brassica carinata*

		Number of *B. carinata* accessions	
Institute Code	**Full name of institute**	**Online databases**	**Survey 2022**
ETH085	Ethiopian Biodiversity Institute	639	
GBR006	Warwick Genetic Resources Unit	10	271
PAK001	Plant Genetic Resources Program	243	
DEU146/ DEU271	Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research	142	142
TWN001	World Vegetable Center	134	133
AUS165	Australian Grains Genebank, Department of Economic Development Jobs Transport and Resources	129	120
ZMB048	National Plant Genetic Resources Centre	109	
NLD037	Centre for Genetic Resources, the Netherlands	108	108
IND001	National Bureau of Plant Genetic Resources	73	104
CAN004	Plant Gene Resources of Canada, Saskatoon Research and Development Centre	91	92
USA020	North Central Regional Plant Introduction Station, USDA-ARS, NCRPIS	78	78
RUS001	N.I. Vavilov Research Institute of Plant Industry	55	41
CZE122	Gene bank	37	41
ESP026	Generalidad Valenciana. Universidad Politècnica de Valencia. Escuela Técnica Superior de Ingenieros Agrónomos. Banco de Germoplasma	25	
UGA132	Plant Genetic Resource Centre	17	
JPN183	NARO Genebank	10	
ERI003	National Agricultural Research Institute	9	
TZA016	National Plant Genetic Resources Centre	8	
ITA331	DI3A University of Catania		6
KEN212	Genetic Resources Research Institute	6	

Table 4. *Brassica rapa*

Institute Code	Full name of Institute	Number of *B. rapa* accessions: Online data-bases	Survey
IND001	National Bureau of Plant Genetic Resources	4,693	6,009
AUS165	Australian Grains Genebank, Department of Economic Development Jobs Transport and Resources	2,684	2,502
RUS001	N.I. Vavilov Research Institute of Plant Industry	352	2,066
IND001	National Bureau of Plant Genetic Resources	4,693	6,009
AUS165	Australian Grains Genebank, Department of Economic Development Jobs Transport and Resources	2,684	2,502
RUS001	N.I. Vavilov Research Institute of Plant Industry	352	2,066
JPN183	NARO Genebank	1,569	
PAK001	Plant Genetic Resources Program	1,380	
TWN001	World Vegetable Center	1,091	1,088
DEU146/271	Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research	804	794
GBR006	Warwick Genetic Resources Unit	713	784
CAN004	Plant Gene Resources of Canada, Saskatoon Research and Development Centre	772	747
USA020	North Central Regional Plant Introduction Station, USDA-ARS, NCRPIS	675	675
EST019	Estonian Crop Research Institute	512	546
PRT001	Portuguese Bank of Plant Germplasm	381	
USA003	Northeast Regional Plant Introduction Station, Plant Genetic Resources Unit, USDA-ARS, New York State Agricultural Experiment Station, Cornell University	358	
NLD037	Centre for Genetic Resources, the Netherlands	356	356
ESP009	Consejo Superior de Investigaciones Científicas. Misión Biológica de Galicia	247	
SWE054	Nordic Genetic Resource Center	230	229
ESP027	Gobierno de Aragón. Centro de Investigación y Tecnología Agroalimentaria. Banco de Germoplasma de Hortícolas	42	173
CZE122	Gene bank	126	47
IRL029	Department of Agriculture, Fisheries and Food, National Crop Variety Testing Centre	125	
POL003	Plant Breeding and Acclimatization Institute	125	

Table 5. *Brassica napus*

Institute Code	Full name of Institute	Number of *B. napus* accessions: Online databases	Survey 2022
FRA010	Institut de Génétique Environnement et Protection des Plantes, Plant Biology and Breeding, INRA Ploudaniel	71	2,161
RUS001	VIR		1,641
AUS165	Australian Grains Genebank, Department of Economic Development Jobs Transport and Resources	1,478	1,202
DEU271	External Branch North of the Department Genebank, IPK, Oil Plants and Fodder Crops in Malchow	1,155	1,235
JPN183	NARO Genebank	965	
CZE122	Gene bank	830	12
BLR011	Republican Unitary Enterprise 'Scientific Practical Centre of the National Academy of Sciences of Belarus for Arable Farming'	820	
UKR013	Ivano-Frankivs'k Institute of Agroindustrial Production	679	
USA020	North Central Regional Plant Introduction Station, USDA-ARS, NCRPIS	650	657
PAK001	Plant Genetic Resources Program	573	
BRA003	Embrapa Recursos Genéticos e Biotecnologia	551	
GBR006	Warwick Genetic Resources Unit	451	485

		Number of *B. napus* accessions	
Institute Code	Full name of Institute	Online databases	Survey 2022
POL003	Plant Breeding and Acclimatization Institute	475	
CAN004	Plant Gene Resources of Canada, Saskatoon Research and Development Centre	458	459
BGR001	Institute for Plant Genetic Resources ‘K.Malkov’	408	
IND001	National Bureau of Plant Genetic Resources	258	343
SWE054	Nordic Genetic Resource Center	343	343
NLD037	Centre for Genetic Resources, the Netherlands	222	222
EGY087	National Gene Bank	175	
MNG030	Plant Science Agricultural Research and Training Institute	142	

Table 6. *Brassica juncea*

		Number of *B. juncea* accessions	
Institute Code	Full name of Institute	Online databases	Survey
IND001	National Bureau of Plant Genetic Resources	7,909	12,979
RUS001	N.I. Vavilov Research Institute of Plant Industry	1,365	1,380
AUS165	Australian Grains Genebank, Department of Economic Development Jobs Transport and Resources	1,361	1,265
PAK001	Plant Genetic Resources Program	830	
CAN004	Plant Gene Resources of Canada, Saskatoon Research and Development Centre	491	562
UKR008	Ustymivka Experimental Station of Plant Production	467	
USA020	North Central Regional Plant Introduction Station, USDA-ARS, NCRPIS	439	439
DEU271	External Branch North of the Department Genebank, IPK, Oil Plants and Fodder Crops in Malchow	310	308
JPN183	NARO Genebank	224	
TWN001	World Vegetable Center	210	207
LKA036	Plant Genetic Resources Centre	120	
FRA010	INRAE		101
ARE003	International Center for Biosaline Agriculture	100	100
CZE122	Gene bank	96	5
UKR012	Institute of Oil Crops	89	
GBR006	Warwick Genetic Resources Unit	87	87
USA003	Northeast Regional Plant Introduction Station, Plant Genetic Resources Unit, USDA-ARS, New York State Agricultural Experiment Station, Cornell University	60	
EGY087	National Gene Bank	56	
BGR001	Institute for Plant Genetic Resources ‘K.Malkov’	53	
BLR011	Republican Unitary Enterprise ‘Scientific Practical Centre of the National Academy of Sciences of Belarus for Arable Farming’	47	

Appendix 4. Details of survey respondents and strategy co-developers

Agrifood Research and Technology Centre of Aragón
Avda. Montañana 930
Zaragoza 50014 Spain
www.cita-aragon.es/en
Contact: Cristina Mallor

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110 Natimuk Road
Horsham, Victoria 3400 Australia
Contact: Dr Sally Norton

Austrian Agency for Health and Food Safety
Wieningerstraße 8
Linz 4020 Austria
www.genbank.at
Contact: Sylvia Vogl

Banco de Germoplasma - Universidade da Madeira
Campus da Penteada
Funchal Madeira 9020-105 Portugal
https://isoplexis.uma.pt
Contact: Humberto Nóbrega

Centre for Genetic Resources the Netherlands
Droevendaalsesteeg 1
Wageningen, Gelderland 6708PD The Netherlands
www.cgn.wur.nl
Contact: Noor Bas

Centro de Conservación de la Biodiversidad Agrícola de Tenerife (CCBAT)
Calle Retama 2. Jardín de Aclimatación de La Orotava.
Puerto de La Cruz
Santa Cruz de Tenerife 38400 Spain
www.ccbat.es
Contact: Desirée Afonso Morales

Crop Research Institute
Drnovská 507/73
Praha 6 – Ruzyně 161 06 Czechia
www.vurv.cz/en/
Contact: Pavel Kopecký

DI3A University of Catania
Via Valdisavoia 5
Catania 95123 Italy
Contact: Branca Ferdinando

Estonian Crop Research Institute
J. Aamisepa 1
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Jõgeva County 48309 Estonia
etki.ee
Contact: Külli Annamaa

Federal Research Center the N.I. Vavilov All Russian Institute of Plant Genetic Resources (VIR)
42-44, Bolshaya Morskaya Str.
Saint-Petersburg 190000 Russian Federation
www.vir.nw.ru
Contact: Anna Artemeva (Artemyeva)

Garden Organic (Heritage Seed Library)
Ryton Organic Gardens, Wolston Lane
Coventry CV8 3LG GBR
www.gardenorganic.org.uk/hsl
Contact: Catrina Fenton

Greek Gene Bank, Hellenic Agricultural Organisation-Dimitra
Institute of Plant Breeding & Genetic Resources
PO Box 60458
Thermi, Thessaloniki GR-570 01 Greece
https://ipgrb.gr
Contact: Catherine M Cook

ICAR-National Bureau of Plant genetic Resources
Pusa campus, New Delhi-110012
Delhi 110012 India
www.nbpgr.ernet.in
Contact: Badal Singh

INRAE
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Ploudaniel
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Contact: Vincent Richer

Institute of Plant Genetic Resources / Agricultural University of Tirana
Rruga Siri Kodra, 132/1
Tirana 1016 Albania
http://qrgj.org
Contact: Sokrat Jani

International Center for Biosaline Agriculture
Al Ruwayyah 2, Academic City
Dubai 14660
United Arab Emirates
www.biosaline.org

Leibniz Institute of Plant Genetics and Crop Plant Research (IPK)
Corrensstrasse 3
Seeland, OT Gatersleben
Saxony Anhalt 6466 Germany
www.ipk-gatersleben.de
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Margot Forde Germplasm Centre (NZ)
C/o AgResearch Ltd, Private Bag 11008
Palmerston North
Manawatu-Whanganui 4442 New Zealand
www.margotforde.com
Contact: Kioumars Ghamkhar

National Gene Bank of Tunisia (NGBT)
Boulevard Leader Yasser Arafat
Charguia 1
Tunis 1080 Tunisia
Contact: Najla Mezghani

NordGen – Nordic Genetic Resource Center
Växthusvägen 12
Alnarp
Skåne 23456 Sweden
www.nordgen.org
Contact: Mohammad El-khalifeh

Plant Gene Resources of Canada
107 Science Place
Saskatoon
Saskatchewan S7N 0X2 Canada
https://pgrc-rpc.agr.gc.ca/gringlobal/landing
Contact: Dallas Kessler

Royal Botanic Gardens Kew
Wakehurst Place
Ardingly
West Sussex RH17 6TN UK
www.kew.org/science/collections-and-resources/research-facilities/millennium-seed-bank
Contact: Sharon Balding

UK Vegetable Genebank, The University of Warwick
Wellesbourne Campus,
Wellesbourne, Warwick CV35 9EF UK
https://warwick.ac.uk/gru/genebank/
Contact: Charlotte Allender

USDA-ARS Plant Introduction Research Unit, Ames, IA
1305 State Ave
Ames, IA 50014 USA
https://www.ars.usda.gov/midwest-area/ames/plant-introduction-research/
Contact: Laura Fredrick Marek

Verein Arche Noah
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Schiltern, Lower Austria 3553 Austria
www.arche-noah.at/
Contact: Michaela Arndorfer

World Vegetable Center
No. 60, Yiminliao, Shanhua Dist.
Tainan City 741005 Taiwan
https://avrdc.org/

Appendix 5. Standardization of taxa found in Genesys and FAO-WIEWS to conduct data analysis.

Taxon as found in databases	Standardized taxon
Brassica cavinata	*Brassica carinata* A. Braun
Brassica	*Brassica* L.
Brassica napus	*Brassica napus* L.
Brassica alboglabra	*Brassica oleracea* var. *alboglabra* (L. H. Bailey) Musil
Brassica atlantica	*Brassica insularis* Moris
Brassica aucheri	*Brassica aucheri* Boiss.
Brassica balearica	*Brassica balearica* Pers.
Brassica barrelieri	*Brassica barrelieri* (L.) Janka
Brassica barrelieri subsp. *barrelieri*	*Brassica barrelieri* (L.) Janka
Brassica barrelieri subsp. *oxyrrhina*	*Brassica oxyrrhina* (Coss.) Willk.
Brassica barrelieri var. *sabularia*	*Brassica barrelieri* (L.) Janka
Brassica bivoniana	*Brassica villosa* Biv.
Brassica bourgeaui	*Brassica bourgeaui* (Webb ex Christ) Kuntze
Brassica campestris	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris L. var. *oleifera*. Metzg.	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris L. var. *oleifera*. Metzg.	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris subsp. *chinensis*	*Brassica rapa* subsp. *chinensis* (L.) Hanelt
Brassica campestris subsp. *oleifera*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris subsp. *pekinensis*	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica campestris subsp. *rapifera*	*Brassica rapa* subsp. *rapa* L.
Brassica campestris var. *candle*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *indian rape*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *oleifera* f. *biennis* d.c.	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *pekinensis*	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica campestris var. *pollar*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *rapa*	*Brassica rapa* subsp. *rapa* L.
Brassica campestris var. *rapifera*	*Brassica rapa* subsp. *rapa* L.
Brassica campestris var. *silvestre*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *sv 68/420*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *sv 72/1002*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *sv 73 /0063*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *sv 73/617*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *sv 731604*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *sv torpe*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *tobin*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *toria*	*Brassica rapa* subsp. *dichotoma* (Rox*B.*) Hanelt
Brassica campestris var. *yellow sarson*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica campestris var. *silvestre*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica capitata	*Brassica oleracea* var. *capitata* L.
Brassica capitata convar. *capitata* (l.) alef. var. *rubra*	*Brassica oleracea* var. *capitata* L.
Brassica carinata	*Brassica carinata* A. Braun
Brassica carinata var. *mbeya green*	*Brassica carinata* A. Braun
Brassica cauliflora	*Brassica oleracea* var. *botrytis* L.
Brassica caulorapa	*Brassica oleracea* var. *gongylodes* L.
Brassica chinensis	*Brassica rapa* subsp. *chinensis* (L.) Hanelt
Brassica chinensis var. *chinensis*	*Brassica rapa* subsp. *chinensis* (L.) Hanelt
Brassica chinensis var. *parachinensis*	*Brassica rapa* subsp. *chinensis* (L.) Hanelt
Brassica chinensis var. *pekinensis*	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica composita	*Brassica* x *composita*

Taxon as found in databases	Standardized taxon
Brassica cretica	*Brassica cretica* Lam.
Brassica cretica subsp. *aegaea*	*Brassica cretica* subsp. *aegaea* (Heldr. & Halacsy) Snogerup et al.
Brassica cretica subsp. *cretica*	*Brassica cretica* subsp. *cretica* Lam.
Brassica cretica subsp. *laconica*	*Brassica cretica* subsp. *laconica* M. A. Gust. & Snogerup
Brassica cretica subsp. *nivea*	*Brassica cretica* subsp. *cretica* Lam.
Brassica deflexa	*Brassica deflexa* Boiss.
Brassica deflexa subsp. *deflexa*	*Brassica deflexa* subsp. *deflexa* Boiss.
Brassica deflexa subsp. *leptocarpa*	*Brassica deflexa* subsp. *leptocarpa* (Boiss.) Hedge
Brassica desnottesii	*Brassica desnottesii* Em*B.* & Maire
Brassica dimorpha	*Brassica dimorpha* Coss. & Durieu
Brassica drepanensis	*Brassica drepanensis* (Caruel) Damanti
Brassica elongata	*Brassica elongata* Ehrh.
Brassica elongata subsp. *elongata*	*Brassica elongata* subsp. *elongata* Ehrh.
Brassica elongata subsp. *integrifolia*	*Brassica elongata* subsp. *integrifolia* (Boiss.) Breistr.
Brassica elongata subsp. *subscaposa*	*Brassica elongata* subsp. *subscaposa* (Maire & Weiller) Maire
Brassica erectus	*Brassica* spp.
Brassica fruticulosa	*Brassica fruticulosa* Cirillo
Brassica fruticulosa subsp. *cossoneana*	*Brassica fruticulosa* Cirillo subsp. *cossoniana* (Boiss. & Reut.) Maire
Brassica fruticulosa subsp. *djafarensis*	*Brassica fruticulosa* Cirillo
Brassica fruticulosa subsp. *fruticulosa*	*Brassica fruticulosa* subsp. *fruticulosa* Cirillo
Brassica fruticulosa subsp. *glaberrima*	*Brassica fruticulosa* subsp. *glaberrima* (Pomel) Batt.
Brassica fruticulosa subsp. *mauritanica*	*Brassica fruticulosa* subsp. *mauritanica* (Coss.) Maire
Brassica fruticulosa subsp. *pomeliana*	*Brassica fruticulosa* subsp. *pomeliana* Maire
Brassica fruticulosa subsp. *radicata*	*Brassica fruticulosa* subsp. *radicata* (Desf.) Batt.
Brassica gemmifera	*Brassica oleracea* L.
Brassica gravinae	*Brassica gravinae* Ten.
Brassica gravinae var. *brachyloma*	*Brassica gravinae* Ten.
Brassica gravinae var. *djurdjurae*	*Brassica gravinae* Ten.
Brassica hilarionis	*Brassica hilarionis* Post
Brassica hirta	*Sinapis alba* subsp. *alba* L.
Brassica hybrid	*Brassica hybrid*
*Brassica hybrid*e	*Brassica hybrid*
Brassica incana	*Brassica incana* Ten.
Brassica insularis	*Brassica insularis* Moris
Brassica insularis var. *angustiloba*	*Brassica insularis* Moris
Brassica insularis var. *aquellae*	*Brassica insularis* Moris
Brassica insularis var. *ayliesii*	*Brassica insularis* Moris
Brassica insularis var. *latiloba*	*Brassica insularis* Moris
Brassica italica	*Brassica oleracea* var. *italica* Plenck
Brassica japonica	*Brassica rapa* subsp. *nipposinica* (L. H. Bailey) Hanelt
Brassica juncea	*Brassica juncea* (L.) Czern.
Brassica juncea *Cernua* Group	*Brassica juncea* (L.) Czern.
Brassica juncea *crispifolia*	*Brassica juncea* var. *crispifolia* L. H. Bailey
Brassica juncea *cvg daulat*	*Brassica juncea* (L.) Czern.
Brassica juncea Czern.	*Brassica juncea* (L.) Czern.
Brassica juncea group oilseed	*Brassica juncea* (L.) Czern.
Brassica juncea group vegetable	*Brassica juncea* (L.) Czern.
Brassica juncea juncea integlifolia	*Brassica juncea* (L.) Czern.
Brassica juncea Integlifolia Group	*Brassica juncea* (L.) Czern.

Taxon as found in databases	Standardized taxon
Brassica juncea L.	*Brassica juncea* (L.) Czern.
Brassica juncea L. Czern.	*Brassica juncea* (L.) Czern.
Brassica juncea L. subsp. *oleifera* Metzg.	*Brassica juncea* subsp. *juncea* (L.) Czern.
Brassica juncea subsp. *areptana*	*Brassica juncea* (L.) Czern.
Brassica juncea subsp. *cernua*	*Brassica juncea* (L.) Czern.
Brassica juncea subsp. *integrifolia*	*Brassica juncea* subsp. *integrifolia* (H. West) Thell.
Brassica juncea subsp. *integrifolia* var. *crispifolia*	*Brassica juncea* (L.) Czern.
Brassica juncea subsp. *integrifolia* var. *integrifolia*	*Brassica juncea* (L.) Czern.
Brassica juncea subsp. *integrifolia* var. *rugosa*	*Brassica juncea* (L.) Czern.
Brassica juncea subsp. *integrifolia* var. *subintegrifolia*	*Brassica juncea* (L.) Czern.
Brassica juncea subsp. *juncea*	*Brassica juncea* subsp. *juncea* (L.) Czern.
Brassica juncea subsp. *juncea* var. *juncea*	*Brassica juncea* (L.) Czern.
Brassica juncea subsp. *napiformis*	*Brassica juncea* subsp. *napiformis* (Pailleux & Bois) Gladis
Brassica juncea subsp. *tsatsai*	*Brassica juncea* var. *tumida* M. Tsen & S. H. Lee
Brassica juncea subsp. *tsatsai* var. *multiceps*	*Brassica juncea* (L.) Czern.
Brassica juncea subspp. *integrifolia* var. *rugosa*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *88-f1-221*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *88-f1-354*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *88-f1-421*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *88-f5-304*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *88-f6-71*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *88-fi-515*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *careptana*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *cereptana*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *crispifolia*	*Brassica juncea* var. *crispifolia* L. H. Bailey
Brassica juncea var. *cuneifolia*	*Brassica juncea* var. *rugosa* (Rox*B.*) M. Tsen & S. H. Lee
Brassica juncea var. *integrifolia*	*Brassica juncea* var. *integrifolia* (H. West) Sinskaya
Brassica juncea var. *japonica*	*Brassica juncea* var. *japonica* (Thun*B.*) L. H. Bailey
Brassica juncea var. *juncea*	*Brassica juncea* subsp. *juncea* (L.) Czern.
Brassica juncea var. *laevigata*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *ld2 86-07*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *longidens*	*Brassica juncea* var. *longidens* L. H. Bailey
Brassica juncea var. *mongolica*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *multiceps*	*Brassica juncea* var. *multiceps* M. Tsen & S. H. Lee
Brassica juncea var. *r 3243*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *r 3245*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *r h.30*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *rugosa*	*Brassica juncea* var. *rugosa* (Rox*B.*) M. Tsen & S. H. Lee
Brassica juncea var. *sareptana*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *strumata*	*Brassica juncea* var. *strumata* M. Tsen & S. H. Lee
Brassica juncea var. *suberispifolia*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *subintegrvifol.*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *subsareptana*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *t 59*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *t.003-189*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *t.003-190*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *t.003-193*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *t.003-195*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *t.003-196*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *t.003-208*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *vugosa*	*Brassica juncea* (L.) Czern.

Taxon as found in databases	Standardized taxon
Brassica juncea var. *zem-i*	*Brassica juncea* (L.) Czern.
Brassica juncea var. *integrifolia*	*Brassica juncea* subsp. *integrifolia* (H. West) Thell.
Brassica L.	*Brassica* L.
Brassica macrocarpa	*Brassica macrocarpa* Guss.
Brassica maurorum	*Brassica maurorum* Durieu
Brassica mixed	*Brassica* spp.
Brassica monocarpa	*Brassica* spp.
Brassica montana	*Brassica montana* Pourr.
Brassica napoBrassica	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus	*Brassica napus* L.
Brassica napus biennis	*Brassica napus* f. *napus* L.
Brassica napus convar. *napus* forma *annua*	*Brassica napus* L.
Brassica napus convar. *napus* forma *napus*	*Brassica napus* L.
Brassica napus f. *annua*	*Brassica napus* f. *annua* (Schubl. & G. Martens) Thell.
Brassica napus f. *biennis*	*Brassica napus* f. *napus* L.
Brassica napus f. *oleifera*	*Brassica napus* subsp. *napus* L.
Brassica napus f. *oleifera annua*	*Brassica napus* L.
Brassica napus f. *oleifera biennis*	*Brassica napus* L.
Brassica napus f. *oleifera italica*	*Brassica napus* L.
Brassica napus f.*oleifera biennis*	*Brassica napus* L.
Brassica napus f.*oleifera annua*	*Brassica napus* L.
Brassica napus f.*oleifera biennis*	*Brassica napus* L.
Brassica napus group fodder rape	*Brassica napus* L.
Brassica napus group spring oilseed rape	*Brassica napus* L.
Brassica napus group swede	*Brassica napus* L.
Brassica napus group winter oilseed rape	*Brassica napus* L.
Brassica napus L.	*Brassica napus* L.
Brassica napus L. ssp.*oleifera* (Metzg.) Sinsk	*Brassica napus* subsp. *napus* L.
Brassica napus L. ssp.*oleifera* Ibemalis (Metzg.) Sinsk	*Brassica napus* subsp. *napus* L.
Brassica napus L. ssp.*oleifera* Ibemalis metzg. f.*biennis*	*Brassica napus* subsp. *napus* L.
Brassica napus L. ssp.*oleifera* Metzg.	*Brassica napus* subsp. *napus* L.
Brassica napus L. subsp. *oleifera* (Metzg.) Sinsk	*Brassica napus* subsp. *napus* L.
Brassica napus L. subsp. *oleifera* Metzg.	*Brassica napus* subsp. *napus* L.
Brassica napus L. var. *oleifera*. aestiva Metzg.	*Brassica napus* L.
Brassica napus L. var. *oleifera*. Metzg.	*Brassica napus* L.
Brassica napus L. var. *oleifera*.aestiva Metzg.	*Brassica napus* L.
Brassica napus L. var.*oleifera*.aestiva Metzg.	*Brassica napus* L.
Brassica napus napoBrassica	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus Napo*Brassica* Group	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus	*Brassica napus* subsp. *napus* L.
Brassica napus oleifera	*Brassica napus* subsp. *napus* L.
Brassica napus pabularia	*Brassica napus* var. *pabularia* (DC.) Alef.
Brassica napus rapifera	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus ssp. *oleifera*	*Brassica napus* subsp. *napus* L.
Brassica napus ssp. *oleifera biennis*	*Brassica napus* L.
Brassica napus subsp. *napoBrassica*	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus subsp. *napus*	*Brassica napus* subsp. *napus* L.
Brassica napus subsp. *napus* convar. *annua forma*	*Brassica napus* L.
Brassica napus subsp. *napus* forma *annua*	*Brassica napus* L.
Brassica napus subsp. *napus* forma *biennis*	*Brassica napus* L.
Brassica napus subsp. *napus* var. *napus* f. *annua*	*Brassica napus* L.

Taxon as found in databases	Standardized taxon
Brassica napus subsp. *napus* var. *napus* f. *biennis*	*Brassica napus* L.
Brassica napus subsp. *napus* var. *pabularia*	*Brassica napus* L.
Brassica napus subsp. *oleifera*	*Brassica napus* subsp. *napus* L.
Brassica napus subsp. *pabularia*	*Brassica napus* var. *pabularia* (DC.) Alef.
Brassica napus Subsp. *rapifera*	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus subsp. *rapifera*	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus subsp. *rapifera* metzger var. alb	*Brassica napus* L.
Brassica napus subsp. *rapifera* metzger var.*alba*	*Brassica napus* L.
Brassica napus subsp. *rapifera* metzger var.flav	*Brassica napus* L.
Brassica napus var. *81-53188b*	*Brassica napus* L.
Brassica napus var. *81-55705b*	*Brassica napus* L.
Brassica napus var. *81-58410k*	*Brassica napus* L.
Brassica napus var. *81-58413k*	*Brassica napus* L.
Brassica napus var. *8155705b*	*Brassica napus* L.
Brassica napus var. *altex*	*Brassica napus* L.
Brassica napus var. *andor*	*Brassica napus* L.
Brassica napus var. *bln-80-245*	*Brassica napus* L.
Brassica napus var. *brutor*	*Brassica napus* L.
Brassica napus var. *candle*	*Brassica napus* L.
Brassica napus var. *christa*	*Brassica napus* L.
Brassica napus var. *cressor*	*Brassica napus* L.
Brassica napus var. *dj-63*	*Brassica napus* L.
Brassica napus var. *glauca*	*Brassica rapa* subsp. *trilocularis* (Rox*B.*) Hanelt
Brassica napus var. *gulliver*	*Brassica napus* L.
Brassica napus var. *hannah*	*Brassica napus* L.
Brassica napus var. *indian rape*	*Brassica napus* L.
Brassica napus var. *karat*	*Brassica napus* L.
Brassica napus var. *line*	*Brassica napus* L.
Brassica napus var. *maluka*	*Brassica napus* L.
Brassica napus var. *marnoo*	*Brassica napus* L.
Brassica napus var. *mary*	*Brassica napus* L.
Brassica napus var. *napoBrassica*	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus var. *napoBrassica* gr. Chou navet	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus var. *napoBrassica* gr. Chou navet cv. Navet d'Aubigny	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus var. *napus*	*Brassica napus* subsp. *napus* L.
Brassica napus var. *napus* f. *annua*	*Brassica napus* L.
Brassica napus var. *napus* f. *annua*	*Brassica napus* L.
Brassica napus var. *napus* f. *biennis*	*Brassica napus* L.
Brassica napus var. *napus* gr. Colza fourrager	*Brassica napus* subsp. *napus* L.
Brassica napus var. *niklas*	*Brassica napus* L.
Brassica napus var. *nokonova*	*Brassica napus* L.
Brassica napus var. *oleifera*	*Brassica napus* subsp. *napus* L.
Brassica napus var. *oleifera* f. *annua*	*Brassica napus* L.
Brassica napus var. *oleifera* f. *biennis*	*Brassica napus* L.
Brassica napus var. *olivia*	*Brassica napus* L.
Brassica napus var. *oro*	*Brassica napus* L.
Brassica napus var. *pabularia*	*Brassica napus* var. *pabularia* (DC.) Alef.
Brassica napus var. *pollar*	*Brassica napus* L.
Brassica napus var. *r 3243*	*Brassica napus* L.
Brassica napus var. *r 3245*	*Brassica napus* L.

Taxon as found in databases	Standardized taxon
Brassica napus var. *rapifera*	*Brassica napus* subsp. *rapifera* Metzg.
Brassica napus var. *regent*	*Brassica napus* L.
Brassica napus var. *rh 30*	*Brassica napus* L.
Brassica napus var. *shiralee*	*Brassica napus* L.
Brassica napus var. *sv 68/420*	*Brassica napus* L.
Brassica napus var. *sv 72/1002*	*Brassica napus* L.
Brassica napus var. *sv 73/604*	*Brassica napus* L.
Brassica napus var. *sv 73/617*	*Brassica napus* L.
Brassica napus var. *sv.73/10063*	*Brassica napus* L.
Brassica napus var. *sv.belle*	*Brassica napus* L.
Brassica napus var. *sv.torpe*	*Brassica napus* L.
Brassica napus var. *sv73/599*	*Brassica napus* L.
Brassica napus var. *t59*	*Brassica napus* L.
Brassica napus var. *tatyoon*	*Brassica napus* L.
Brassica napus var. *tobin*	*Brassica napus* L.
Brassica napus var. *topaz*	*Brassica napus* L.
Brassica napus var. *tower*	*Brassica napus* L.
Brassica napus var. *wesroona*	*Brassica napus* L.
Brassica napus var. *westar*	*Brassica napus* L.
Brassica napus var. *wiklas*	*Brassica napus* L.
Brassica napus var. *willi*	*Brassica napus* L.
Brassica napus var. *ww 1307*	*Brassica napus* L.
Brassica napus var. *zem-1*	*Brassica napus* L.
Brassica narinosa	*Brassica rapa* subsp. *narinosa* (L. H. Bailey) Hanelt
Brassica nigra	*Brassica nigra* (L.) W. D. J. Koch
Brassica nigra 'giselba'	*Brassica nigra* (L.) W. D. J. Koch
Brassica nigra (L.) Koch	*Brassica nigra* (L.) W. D. J. Koch
Brassica nigra subsp. *hispida* var. *orientales*	*Brassica nigra* (L.) W. D. J. Koch
Brassica nigra subsp. *hispida* var. *rigida*	*Brassica nigra* (L.) W. D. J. Koch
Brassica nigra subsp. *nigra* var. *nigra*	*Brassica nigra* (L.) W. D. J. Koch
Brassica nigra subsp. *nigra* var. *pseudocampestris*	*Brassica nigra* (L.) W. D. J. Koch
Brassica nigra var. *abyssinica*	*Brassica nigra* (L.) W. D. J. Koch
Brassica nigra var. *dissecta*	*Brassica nigra* (L.) W. D. J. Koch
Brassica nivalis	*Brassica nivalis* Boiss. & Heldr.
Brassica oleracea	*Brassica oleracea* L.
Brassica oleracea var. *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea acephala	*Brassica oleracea* var. *viridis* L.
Brassica oleracea Acephala Group	*Brassica oleracea* var. *viridis* L.
Brassica oleracea acephala medullosa	*Brassica oleracea* var. *viridis* L.
Brassica oleracea acephala?	*Brassica oleracea* var. *viridis* L.
Brassica oleracea alboglabra	*Brassica oleracea* var. *alboglabra* (L. H. Bailey) Musil
Brassica oleracea Alboglabra Group	*Brassica oleracea* var. *alboglabra* (L. H. Bailey) Musil
Brassica oleracea alboglabra?	*Brassica oleracea* var. *alboglabra* (L. H. Bailey) Musil
Brassica oleracea botrytis	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea botrytis	*Brassica oleracea* L.
Brassica oleracea botrytis cymosa	*Brassica oleracea* L.
Brassica oleracea Botrytis Group	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea capitata	*Brassica oleracea* var. *capitata* L.
Brassica oleracea capitata	*Brassica oleracea* L.
Brassica oleracea Capitata Group	*Brassica oleracea* L.

Taxon as found in databases	Standardized taxon
Brassica oleracea capitata?	*Brassica oleracea* L.
Brassica oleracea chinensis var. *botrytis*	*Brassica oleracea* L.
Brassica oleracea convar. *acephala* var. *gongyloide*	*Brassica oleracea* L.
Brassica oleracea convar. *acephala* var. *sabellica*	*Brassica oleracea* L.
Brassica oleracea convar. *acephala* var. *viridis*	*Brassica oleracea* L.
Brassica oleracea convar. *botrytis*	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea convar. *botrytis* subsp. *asparago*	*Brassica oleracea* L.
Brassica oleracea convar. *botrytis* var. *botrytis*	*Brassica oleracea* L.
Brassica oleracea convar. *botrytis* var. *italica*	*Brassica oleracea* L.
Brassica oleracea convar. *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea convar. *capitata* (l.) alef. var.	*Brassica oleracea* var. *capitata* L.
Brassica oleracea convar. *capitata* var. *alba*	*Brassica oleracea* L.
Brassica oleracea convar. *capitata* var. *capitata*	*Brassica oleracea* L.
Brassica oleracea convar. *capitata* var. *capitata* f	*Brassica oleracea* L.
Brassica oleracea convar. *capitata* var. *sabauda*	*Brassica oleracea* L.
Brassica oleracea convar. *caulorapa*	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea convar. *caulorapa* var. *gongylode*	*Brassica oleracea* L.
Brassica oleracea convar. *gongyloides*	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea convar. *gongyloides* var. *acephal*	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea convar. *oleracea*	*Brassica oleracea* var. *oleracea*
Brassica oleracea convar. *oleracea* var. *gemmifera*	*Brassica oleracea* L.
Brassica oleracea convar. *sabauda* var. *capitata* f	*Brassica oleracea* L.
Brassica oleracea convar. *sabauda* var. *capitata*	*Brassica oleracea* L.
Brassica oleracea convar. *sabauda* var. *capitata* f.	*Brassica oleracea* L.
Brassica oleracea f. *longata*	*Brassica oleracea* L.
Brassica oleracea gemmifera	*Brassica oleracea* L.
Brassica oleracea Gemmifera group	*Brassica oleracea* L.
Brassica oleracea gongylodes	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea group borecole	*Brassica oleracea* L.
Brassica oleracea group broccoli	*Brassica oleracea* L.
Brassica oleracea group brussels sprouts	*Brassica oleracea* L.
Brassica oleracea group cauliflower	*Brassica oleracea* L.
Brassica oleracea group chinese kale	*Brassica oleracea* L.
Brassica oleracea group kohlrabi	*Brassica oleracea* L.
Brassica oleracea group marrowstem kale	*Brassica oleracea* L.
Brassica oleracea group pointed headed cabbage	*Brassica oleracea* L.
Brassica oleracea group red cabbage	*Brassica oleracea* L.
Brassica oleracea group savoy cabbage	*Brassica oleracea* L.
Brassica oleracea group *tronchuda*	*Brassica oleracea* L.
Brassica oleracea group white cabbage	*Brassica oleracea* L.
Brassica oleracea italica	*Brassica oleracea* var. *italica* Plenck
Brassica oleracea Italica Group	*Brassica oleracea* var. *italica* Plenck
Brassica oleracea italica?	*Brassica oleracea* L.
Brassica oleracea L.	*Brassica oleracea* L.
Brassica oleracea L. var. *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea L. var. *botrytis*	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea L. var. *cabbage*	*Brassica oleracea* L.
Brassica oleracea L. var. *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea L. var. *gongylodes*	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea sabauda	*Brassica oleracea* var. *sabauda* L.

Taxon as found in databases	Standardized taxon
Brassica oleracea subsp. *botrytis*	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea subsp. *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea subsp. *capitata* convar. *acephala*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *acephala* galega-kohl	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *acephala* var. *gongylodes*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *acephala* var. *medullosa*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *acephala* var. *palmifolia*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *acephala* var. *sabellica*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *acephala* var. *selenisia*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *acephala* var. *selenisia* f. *selenisia*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *acephala* var. *viridis*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *botrytis*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *botrytis* var. *alboglabra*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *botrytis* var. *botrytis*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *botrytis* var. *italica*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *capitata* var. *capitata*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *capitata* var. *capitata* f. *capitata*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *capitata* var. *capitata* f. *rubra*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *capitata* var. *capitata* forma *capitata*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *capitata* var. *sabauda*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *costata*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *costata* var. *costata*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *costata* var. *helmii*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *fruticosa* var. *ramosa*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *fruticosa* x *B. oleracea* l. ssp. *capitata* (l.) var. *costata* dc.	*Brassica oleracea* L.
Brassica oleracea subsp. *capitata* convar. *gemmifera* var. *gemmifera*	*Brassica oleracea* L.
Brassica oleracea subsp. *capitatoides*	*Brassica oleracea* L.
Brassica oleracea subsp. *cretica*	*Brassica cretica* Lam.
Brassica oleracea subsp. *cretica* var. *aegaea*	*Brassica oleracea* L.
Brassica oleracea subsp. *gongylodes*	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea subsp. *oleracea*	*Brassica oleracea* var. *oleracea*
Brassica oleracea subsp. *orientalis* var. *capitata*	*Brassica oleracea* L.
Brassica oleracea subsp. *robertiana*	*Brassica montana* Pourr.
Brassica oleracea subsp. *rupestris*	*Brassica rupestris* Raf.
Brassica oleracea subsp. *selenisia*	*Brassica oleracea* var. *sabellica* L.
Brassica oleracea subsp. *villosa*	*Brassica villosa* Biv.
Brassica oleracea subsp.*europea*	*Brassica oleracea* L.
Brassica oleracea subsp.*europea* var. *capitata*	*Brassica oleracea* L.
Brassica oleracea tronchuda	*Brassica oleracea* var. *costata* DC.
Brassica oleracea tronchuda ?	*Brassica oleracea* var. *costata* DC.
Brassica oleracea var. *gongyloides*	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea var. *acefala*	*Brassica oleracea* var. *viridis* L.
Brassica oleracea var. *acephala*	*Brassica oleracea* var. *viridis* L.
Brassica oleracea var. *acephala* gr. Chou fourrager	*Brassica oleracea* var. *viridis* L.
Brassica oleracea var. *acephala rubra*	*Brassica oleracea* L.
Brassica oleracea var. *alboglabra*	*Brassica oleracea* var. *alboglabra* (L. H. Bailey) Musil
Brassica oleracea var. *botritys*	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea var. *botriyis*	*Brassica oleracea* var. *botrytis* L.

Taxon as found in databases	Standardized taxon
Brassica oleracea var. *botrytis*	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea var. *botrytis* gr. Chou fleur d'hiver	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea var. *botrytys*	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea var. *bullata*	*Brassica oleracea* var. *gemmifera* DC.
Brassica oleracea var. *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *alba*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé cv. Cabus de Lorient	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé cv. Chou Saint Saëns	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé cv. Sinago	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *pyramidalis* gr. Chou pommé	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *pyramidalis* gr. Chou pommé cv. précoce de Louviers de Dragons	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *rubra*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* forma *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* forma *rubra*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f.*rubra*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *cauliflora*	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea var. *caulorapa*	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea var. *caulorapa* forma *gongylodes*	*Brassica oleracea* L.
Brassica oleracea var. *conica*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *costata*	*Brassica oleracea* var. *costata* DC.
Brassica oleracea var. *gemifera*	*Brassica oleracea* var. *gemmifera* DC.
Brassica oleracea var. *gemmifera*	*Brassica oleracea* var. *gemmifera* DC.
Brassica oleracea var. *gemmifera* gr. Bruxelles	*Brassica oleracea* var. *gemmifera* DC.
Brassica oleracea var. *gongylodes*	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea var. *gongylodes* gr. Chou rave	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea var. *gongyloides*	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea var. *gonygylodes*	*Brassica oleracea* var. *gongylodes* L.
Brassica oleracea var. *italica*	*Brassica oleracea* var. *italica* Plenck
Brassica oleracea var. *italica* plenck	*Brassica oleracea* var. *italica* Plenck
Brassica oleracea var. *italica* Plenk	*Brassica oleracea* var. *italica* Plenck
Brassica oleracea var. *local*	*Brassica oleracea* var. *italica* Plenck
Brassica oleracea var. *medullosa*	*Brassica oleracea* var. *medullosa* Thell.
Brassica oleracea var. *medullosa* gr. Chou fourrager	*Brassica oleracea* var. *medullosa* Thell.
Brassica oleracea var. *oleracea*	*Brassica oleracea* var. *oleracea*
Brassica oleracea var. *palmifolia*	*Brassica oleracea* var. *palmifolia* DC.
Brassica oleracea var. *ramosa*	*Brassica oleracea* var. *ramosa* DC.
Brassica oleracea var. *ramosa* gr. Chou fourrager	*Brassica oleracea* var. *ramosa* DC.
Brassica oleracea var. *rubra*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *sabauda*	*Brassica oleracea* var. *sabauda* L.
Brassica oleracea var. *sabauda* gr. Chou pommé cv. Milan de Pontoise	*Brassica oleracea* var. *sabauda* L.
Brassica oleracea var. *sabellica*	*Brassica oleracea* var. *sabellica* L.
Brassica oleracea var. *talica*	*Brassica oleracea* var. *italica* Plenck
Brassica oleracea var. *viridis*	*Brassica oleracea* var. *viridis* L.
Brassica oleracea var. *viridis*	*Brassica oleracea* var. *viridis* L.
Brassica oleracea var. *botrytis*	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea var. *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata*, f.*alba*	*Brassica oleracea* var. *capitata* L.

Taxon as found in databases	Standardized taxon
Brassica oleracea var. *cauliflora*	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea var. *italica*	*Brassica oleracea* var. *italica* Plenck
Brassica oleracea var. *oleracea*	*Brassica oleracea* var. *oleracea*
Brassica oleracea viridis	*Brassica oleracea* var. *viridis* L.
Brassica oleracea x *B. rapa Pekinensis* Group	*Brassica oleracea* x *B. rapa*
Brassica oleraceae	*Brassica oleracea* L.
Brassica oleraceae var. *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleraceae var.*capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oxyrrhina	*Brassica oxyrrhina* (Coss.) Willk.
Brassica pekinensis	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica perviridis	*Brassica rapa* var. *perviridis* L. H. Bailey
Brassica procumbens	*Brassica procumbens* (Poir.) O. E. Schulz
Brassica purpuraria	*Brassica rapa* L.
Brassica rapa	*Brassica rapa* L.
Brassica rapa and *napus*	*Brassica rapa* L.
Brassica rapa broccoletto gp	*Brassica rapa* L.
Brassica rapa chinensis	*Brassica rapa* subsp. *chinensis* (L.) Hanelt
Brassica rapa Chinensis Group	*Brassica rapa* subsp. *chinensis* (L.) Hanelt
Brassica rapa convar. *rapa*	*Brassica rapa* subsp. *rapa* L.
Brassica rapa forma *praecox*	*Brassica rapa* L.
Brassica rapa group broccoletto	*Brassica rapa* L.
Brassica rapa group chinese cabbage	*Brassica rapa* L.
Brassica rapa group fodder turnip	*Brassica rapa* L.
Brassica rapa group komatsuna	*Brassica rapa* L.
Brassica rapa group mizuna	*Brassica rapa* L.
Brassica rapa group pak choi	*Brassica rapa* L.
Brassica rapa group spring turnip oilseed rape	*Brassica rapa* L.
Brassica rapa group turnip greens	*Brassica rapa* L.
Brassica rapa group vegetable turnip	*Brassica rapa* L.
Brassica rapa group winter turnip oilseed rape	*Brassica rapa* L.
Brassica rapa group yellow *sarson*	*Brassica rapa* L.
Brassica rapa Japonica Group	*Brassica rapa* L.
Brassica rapa L. ssp. *oleifera* (DC.) Metzg.	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa L. subsp. *oleifera* (DC.) Metzg.	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa Narinosa Group	*Brassica rapa* L.
Brassica rapa neep greens gp	*Brassica rapa* L.
Brassica rapa nipposinica	*Brassica rapa* subsp. *nipposinica* (L. H. Bailey) Hanelt
Brassica rapa oleifera	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa Oleifera Group	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa pak choi group	*Brassica rapa* L.
Brassica rapa parachinensis	*Brassica rapa* var. *parachinensis* (L. H. Bailey) Hanelt
Brassica rapa Parachinensis Group	*Brassica rapa* var. *parachinensis* (L. H. Bailey) Hanelt
Brassica rapa pekinensis	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica rapa Pekinensis Group	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica rapa Pekinensis Group x *B. juncea*	*Brassica rapa* x *B. juncea*
Brassica rapa Perviridis Group	*Brassica rapa* L.
Brassica rapa purpurea	*Brassica rapa* L.
Brassica rapa	*Brassica rapa* subsp. *rapa* L.
Brassica rapa Rapifera Group	*Brassica rapa* subsp. *rapa* L.
Brassica rapa ssp. *oleifera*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa ssp. *pekinensis*	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt

Taxon as found in databases	Standardized taxon
Brassica rapa ssp. *rapa*	*Brassica rapa* subsp. *rapa* L.
Brassica rapa ssp. *sylvestris*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa subsp. *rapa*	*Brassica rapa* subsp. *rapa* L.
Brassica rapa subsp. *Brassica campestris*	*Brassica rapa* L.
Brassica rapa subsp. *campestris*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa subsp. *chinensis*	*Brassica rapa* subsp. *chinensis* (L.) Hanelt
Brassica rapa subsp. *chinensis* var. *chinensis*	*Brassica rapa* L.
Brassica rapa subsp. *chinensis* var. communis	*Brassica rapa* L.
Brassica rapa subsp. *chinensis* var. *parachinensis*	*Brassica rapa* L.
Brassica rapa subsp. *chinensis* var. *rosularis*	*Brassica rapa* L.
Brassica rapa subsp. *dichotoma*	*Brassica rapa* subsp. *dichotoma* (Rox*B.*) Hanelt
Brassica rapa subsp. *indoafghanica* convar. *ferganica*	*Brassica rapa* L.
Brassica rapa subsp. *narinosa*	*Brassica rapa* subsp. *narinosa* (L. H. Bailey) Hanelt
Brassica rapa subsp. *nipposinica*	*Brassica rapa* subsp. *nipposinica* (L. H. Bailey) Hanelt
Brassica rapa subsp. *nipposinica* var. *chinoleifera*	*Brassica rapa* L.
Brassica rapa subsp. *nipposinica* var. *dissecta*	*Brassica rapa* L.
Brassica rapa subsp. *oleifera*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa subsp. *oleifera* (*ruvo-gruppe*)	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa subsp. *oleifera* var. *silvestris*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa subsp. *oliefera*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa subsp. *pekinensis*	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica rapa subsp. *pekinensis* var. *glabra*	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica rapa subsp. *pekinensis* var. *laxa*	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica rapa subsp. *pekinensis* var. *pandurata*	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica rapa subsp. *pekinensis* x *B. oleracea* l.	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica rapa subsp. *rapa*	*Brassica rapa* subsp. *rapa* L.
Brassica rapa subsp. *rapa* gr. Navet	*Brassica rapa* subsp. *rapa* L.
Brassica rapa subsp. *rapa* gr. Navet cv. navet de Viarme	*Brassica rapa* subsp. *rapa* L.
Brassica rapa subsp. *rapa* gr. Navet cv. plat / de treignac	*Brassica rapa* subsp. *rapa* L.
Brassica rapa subsp. *rapa* gr. Navet cv. rave d'oulles	*Brassica rapa* subsp. *rapa* L.
Brassica rapa subsp. *rapa* gr. Navet cv. rave de treignac	*Brassica rapa* subsp. *rapa* L.
Brassica rapa subsp. *rapa* gr. Navet cv. rave plate	*Brassica rapa* subsp. *rapa* L.
Brassica rapa subsp. *rapa* gr. Navet cv. rave plate d'auvergne	*Brassica rapa* subsp. *rapa* L.
Brassica rapa subsp. *rapifera*	*Brassica rapa* subsp. *rapa* L.
Brassica rapa subsp. *sarson*	*Brassica rapa* subsp. *trilocularis* (Rox*B.*) Hanelt
Brassica rapa subsp. *silvestris*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa subsp. *sylvestris*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa subsp. *trilocularis*	*Brassica rapa* subsp. *trilocularis* (Rox*B.*) Hanelt
Brassica rapa subsp. *dichotoma*	*Brassica rapa* subsp. *dichotoma* (Rox*B.*) Hanelt
Brassica rapa subsp. *japonica*	*Brassica rapa* subsp. *japonica* Shebalina
Brassica rapa sylvestris	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa syn. *Brassica campestris*	*Brassica rapa* L.
Brassica rapa var. *alba*	*Brassica rapa* L.
Brassica rapa var. *amplexicaulis*	*Brassica rapa* subsp. *chinensis* (L.) Hanelt
Brassica rapa var. *brown sarson*	*Brassica rapa* L.
Brassica rapa var. *campestris*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa var. *chinensis*	*Brassica rapa* subsp. *chinensis* (L.) Hanelt
Brassica rapa var. *dichotoma*	*Brassica rapa* subsp. *dichotoma* (Rox*B.*) Hanelt
Brassica rapa var. *nipposinica*	*Brassica rapa* subsp. *nipposinica* (L. H. Bailey) Hanelt
Brassica rapa var. *oleifera*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.

Taxon as found in databases	Standardized taxon
Brassica rapa var. *parachinensis*	*Brassica rapa* var. *parachinensis* (L. H. Bailey) Hanelt
Brassica rapa var. *pekinensis*	*Brassica rapa* subsp. *pekinensis* (Lour.) Hanelt
Brassica rapa var. *perviridis*	*Brassica rapa* var. *perviridis* L. H. Bailey
Brassica rapa var. *purpuraria*	*Brassica rapa* var. *purpuraria* (L. H. Bailey) Kitam.
Brassica rapa var. *rapa*	*Brassica rapa* subsp. *rapa* L.
Brassica rapa var. *rapifera* *'milan'*	*Brassica rapa* subsp. *rapa* L.
Brassica rapa var. rossica	*Brassica rapa* L.
Brassica rapa var. *rubra*	*Brassica rapa* L.
Brassica rapa var. *ruvo*	*Brassica rapa* L.
Brassica rapa var. *silvestris*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa var. *silvestris* f. *annua*	*Brassica rapa* L.
Brassica rapa var. *silvestris* f. *autu*.	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica rapa var. *silvestris* f. *biennis*	*Brassica rapa* L.
Brassica rapa var. *silvestris* f. *praecox*	*Brassica rapa* L.
Brassica rapa var. *toria*	*Brassica rapa* L.
Brassica rapa var. *trilocularis*	*Brassica rapa* subsp. *trilocularis* (Rox*B*.) Hanelt
Brassica rapa var. *yellow sarson*	*Brassica rapa* L.
Brassica rapa var. *silvestris*	*Brassica rapa* subsp. *oleifera* (DC.) Metzg.
Brassica repanda	*Brassica repanda* (Willd.) DC.
Brassica repanda subsp. *africana*	*Brassica repanda* subsp. *africana* (Maire) Greuter & Burdet
Brassica repanda subsp. *almeriensis*	*Brassica repanda* subsp. *almeriensis* Gomez-Campo
Brassica repanda subsp. *blancoana*	*Brassica repanda* subsp. *blancoana* (Boiss.) Heywood
Brassica repanda subsp. *cadevallii*	*Brassica repanda* subsp. *cadevallii* (Font Quer) Heywood
Brassica repanda subsp. *cantabrica*	*Brassica repanda* subsp. *cantabrica* (Font Quer) Heywood
Brassica repanda subsp. *confusa*	*Brassica repanda* subsp. *confusa* (Em*B*. & Maire) Heywood
Brassica repanda subsp. *gypsicola*	*Brassica repanda* subsp. *gypsicola* Gomez-Campo
Brassica repanda subsp. *latisiliqua*	*Brassica repanda* subsp. *latisiliqua* (Boiss. & Reut.) Heywood
Brassica repanda subsp. *maritima*	*Brassica repanda* subsp. *maritima* (Willk.) Heywood
Brassica repanda subsp. *nudicaulis*	*Brassica repanda* subsp. *africana* (Maire) Greuter & Burdet
Brassica repanda subsp. *repanda*	*Brassica repanda* subsp. *repanda* (Willd.) DC.
Brassica robertiana	*Brassica montana* Pourr.
Brassica rugosa	*Brassica juncea* var. *rugosa* (Rox*B*.) M. Tsen & S. H. Lee
Brassica rupestris	*Brassica rupestris* Raf.
Brassica rupestris subsp. *glaucescens*	*Brassica rupestris* Raf.
Brassica rupestris subsp. *hispida*	*Brassica rupestris* subsp. *hispida* Raimondo & Mazzola
Brassica ruvo	*Brassica ruvo* L. H. Bailey
*Brassica sabauda*s subsp. *palmifolia*	*Brassica* spp.
Brassica souliei	*Brassica souliei* (Batt.) Batt.
Brassica souliei subsp. *amplexicaulis*	*Brassica souliei* subsp. *amplexicaulis* (Desf.) Greuter & Burdet
Brassica sp	*Brassica* spp.
Brassica sp.	*Brassica* spp.
Brassica sp. var. *kanjiru*	*Brassica* spp.
Brassica sp. *craciferae*	*Brassica* spp.
Brassica spinescens	*Brassica spinescens* Pomel
Brassica spp.	*Brassica* spp.
Brassica subspontanea	*Brassica oleracea* var. *oleracea*
Brassica subspontanea gr. *acephala*	*Brassica oleracea* var. *oleracea*
Brassica subspontanea Lizg.	*Brassica oleracea* var. *oleracea*
Brassica subspontanea planifolia	*Brassica oleracea* var. *oleracea*
Brassica sylvestris	*Brassica oleracea* var. *oleracea*

Taxon as found in databases	Standardized taxon
Brassica sylvestris subsp. *taurica*	*Brassica incana* Ten.
Brassica sylvestris taurica	*Brassica incana* Ten.
Brassica taurica	*Brassica incana* Ten.
Brassica tournefortii	*Brassica tournefortii* Gouan
Brassica tyrrhena	*Brassica tyrrhena* Giotta, Piccitto & Arrigoni
Brassica villosa	*Brassica villosa* Biv.
Brassica villosa bivoniana	*Brassica villosa* Biv.
Brassica villosa drepanensis	*Brassica drepanensis* (Caruel) Damanti
Brassica villosa subsp. *bivoniana*	*Brassica villosa* Biv.
Brassica villosa subsp. *brevisiliqua*	*Brassica villosa* subsp. *brevisiliqua* (Raimondo & Mazzola) Raimondo & Geraci Raimondo & Geraci (Raimondo & Mazzola)
Brassica villosa subsp. *drepanensis*	*Brassica drepanensis* (Caruel) Damanti
Brassica villosa subsp. *tinei*	*Brassica villosa* Biv.
Brassica villosa tinei	*Brassica villosa* Biv.
Brassica villosa	*Brassica villosa* subsp. *villosa*
Brassica x hybrid	hybrid
*Brassica*ceae *Brassica* l. *nigra* Koch.	*Brassica nigra* (L.) W. D. J. Koch
Brassicae napus var. *napro Brassicae*	*Brassica napus* L. subsp. *rapifera* Metzg. (*Brassica napus* Rutabaga Group)
Eruca *loncholoma*	*Brassica loncholoma* Pomel
Sinapis *aucheri*	*Brassica aucheri* Boiss.
Sinapis *nigra*	*Brassica nigra* (L.) W. D. J. Koch
Brassica oleracea var. *botrytis* gr. Chou fleur d'hiver	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé cv. Cabus de Lorient	*Brassica oleracea* var. *capitata* L.
Brassica cretica Lam.	*Brassica cretica* Lam.
Brassica oleracea var. *capitata* f. *pyramidalis* gr. Chou pommé	*Brassica oleracea* var. *capitata* L.
Brassica incana Ten.	*Brassica incana* Ten.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé cv. Sinago	*Brassica oleracea* var. *capitata* L.
Brassica oleraceae, var *capitata*	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *sabauda* gr. Chou pommé cv. Milan de Pontoise	*Brassica oleracea* var. *sabauda* L.
Brassica oeracea	*Brassica oleracea* L.
Brassica juncea (L.) Czern.	*Brassica juncea* (L.) Czern.
Brassica oleracea var. *capitata* f. *pyramidalis* gr. Chou pommé cv. précoce de Louviers de Dragons	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé cv. Chou Saint Saëns	*Brassica oleracea* var. *capitata* L.
Brassica rupestris Raf.	*Brassica rupestris* Raf.
Brassica rapa subsp. *japonica*	*Brassica rapa* subsp. *japonica* Shebalina
Brassica rapa subsp. *rapa* L	*Brassica rapa* subsp. *rapa* L.
Brassica oleracea var. *botrytis* gr. Chou fleur d'hiver	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea var. *botrytis* gr. Chou fleur d'été	*Brassica oleracea* var. *botrytis* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé cv. Cabus de Lorient	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *pyramidalis* gr. Chou pommé	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé cv. Sinago	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *sabauda* gr. Chou pommé cv. Milan de Pontoise	*Brassica oleracea* var. *sabauda* L.
Brassica oleracea var. *capitata* f. *capitata* gr. Chou pommé cv. Chou Saint Saëns	*Brassica oleracea* var. *capitata* L.
Brassica oleracea var. *capitata* f. *pyramidalis* gr. Chou pommé cv. précoce de Louviers de Dragons	*Brassica oleracea* var. *capitata* L.

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