Crop Wild Relatives of Root Vegetables in North America

Justin E. Anderson [1]

Alexandra Campbell [2]

Email colferab@hawaii.edu

Michael B. Kantar [2]

Email kant0063@umn.edu

[1] Department of Molecular Genetics and Physiology of Plants, Ruhr University Bochum, Bochum, Germany

[2] Department of Tropical Plant & Soil Sciences, University of Hawaii at Manoa, Honolulu, HI, USA

Abstract

Root and tuber crops are staples in diets across the world. They are favored due to a large yield associated with the small acreage needed to grow. Generally, they tend to be fairly robust to insect and disease pests and have historically been used as starvation food. Some root and tuber crops, such as potato, sweet potato, or cassava, are the primary source of daily calories for many cultures worldwide. Some tuber crops are only partially domesticated, facilitating the use of crop wild relatives (CWR). Many different cultures have their favorite root crops, but culinary preparation techniques often allow for different tubers to be used, making the acceptance of these crops fairly rapid. Here, we explore the origins and uses of eight tuber and root crops that are important to world diets and have many related wild species in North America.

Keywords

Tubers
Species richness
Germplasm
Plant breeding

Abbreviations

CWR	Crop wild relatives
CIAT	International Center for Tropical Agriculture
FAO	Food and Agriculture Organization of the United Nations
NPGS	US National Plant Germplasm System

8.1. Introduction

Root vegetables are an important source of calories in many parts of the world. The favored root vegetable, as well as the preparation, varies depending on country or culture. Many root vegetables have been transported across the world, becoming naturalized in different areas. It is difficult to make many generalizations about root crops due to the large number of species and vegetative organs that are classified under this broad definition (Table 8.1). Here we explore the CWR of carrot (*Daucus carota* L. *subsp. sativus* L.), sweet potato (*Ipomoea batatas* L.), potato (*Solanum tuberosum* L.), Jerusalem artichoke (*Helianthus tuberosus* L.), jicama (*Pachyrhizus erosus* L.), cocoyam (*Xanthosoma sagittifolium* L.), cassava (*Manihot esculenta (L.) Lam.*), and beet (*Beta vulgaris* L.); these eight common root vegetables are known for their economic importance and occurrence of wild relatives in North America.

Table 8.1

Tuber crop production by country over the most recent 5 years available in FAOStat (FAO 2014)

Country	Crop	Total yield each year (Hg/Ha)				
		2009	2010	2011	2012	2013
Canada	Carrots and turnips	429,415	497,517	506,502	474,370	449,091
	Potatoes	313,126	316,055	295,863	310,155	325,123
	Sugar beet	603,394	495,575	640,496	592,772	672,697
Mexico	Carrots and turnips	260,679	246,947	269,620	264,475	271,622
	Cassava	143,440	131,579	127,352	122,330	146,398
	Potatoes	277,374	277,578	262,734	268,098	267,752
	Roots and tubers, nes[a]	282,617	274,131	266,843	260,069	261,937
	Sugar beet	NA	NA	250,000	180,000	140,000
	Sweet potato	190,454	206,653	201,465	175,168	183,965
	Yautia (cocoyam)	340,000	393,725	421,176	460,502	493,286
United States of America	Carrots and turnips	397,254	421,786	383,489	400,226	384,494
	Potatoes	464,446	452,767	447,140	458,242	463,577
	Sugar beet	581,309	621,142	533,929	655,763	636,939
	Sweet potato	225,200	228,628	233,019	234,472	245,411

[a]**Roots and tubers, nes:**
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"Including inter alia: arracacha (*Arracacia xanthorrhiza* Bancr.); arrow- root (*Maranta arundinacea* L.); chufa (*Cyperus esculentus* L.); sago palm (*Metroxylon spp*.); oca and ullucu (*Oxalis tuberosa* Molina and *Ullucus tuberosus* Caldas); yam bean, jicama (*Pachyrxhizus erosus* (L.) Urb., *P. angulatus* DC.); mashua (*Tropaeolum tuberosum* Ruíz and Pavón); Jerusalem artichoke, topinambur (*Helianthus tuberosus* L.). Because of their limited local importance, some countries report roots and tubers under this commodity heading that are classified individually by FAO" (FAO Stat 2014)
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The concept of gene pools in plant breeding dates back to Harlan and De Wet in the 1970s (Harlan and de Wet 1971). This concept defines boundaries between crops and the often numerous related species remaining in the wild. Experts working to define these pools for all major crop species in the Germplasm Resources Information Network (USDA, ARS 2017) of the US National Plant Germplasm System (NPGS) and the Harlan and De Wet Inventory (http://www.cwrdiversity.org/checklist; Dempewolf et al. 2017) of the Global Crop Diversity Trust have collaborated to create online resources making this valuable plant breeding information readily accessible.

These combined databases were used as the basis for the gene pools defined in this review. Through ongoing plant breeding, many of the CWR belonging to these gene pools have contributed valuable traits important to modern crop production. Crop wild relatives are known to harbor many valuable traits, including resistance to biotic stresses, such as plant diseases or herbivores; tolerance to abiotic stresses, such as drought or frost; and even breeding and agronomic traits like yield and male sterility. These valuable traits are considered “potential breeding uses” when witnessed in the CWR and “confirmed breeding uses” when the trait has been crossed into the domesticated crop (Dempewolf et al. 2017). Crop wild relative exploration continues to suggest great potential in these and many other crop traits.

8.2. Carrot (*Daucus carota* L. Subsp. *sativus* L.)

8.2.1. Introduction

Carrot (*Daucus carota* subsp. *sativus)*, $2n = 2x = 18$, is an important vegetable from the *Apiaceae* family, known for its high nutritional content (provitamin carotenoids). Breeding efforts have significantly increased carotenoid concentration and recently unlocked the underlying mechanism (Iorizzo et al. 2016). There are several important crops within the *Apiaceae* family, including celery, parsley, fennel, dill, coriander, aniseed, cumin, and caraway. In addition to food uses, many different carrot species have traditionally been used for medicinal purposes (Grzebelus et al. 2011). Carrot, generally grown as a biennial, was domesticated in Central Asia around 1,100 years ago (Iorizzo et al. 2013). Originally yellow or purple, the iconic orange carrot wasn’t reported until the 1600s in Europe (Simon 2000).

8.2.2. Crop Wild Relatives and Wild Use

Domestic carrot has widely hybridized with wild carrots from North America and Europe, even suggesting that the origin of the only North American CWR, *Daucus pusillus* Michx., might actually have been an introduction of wild carrot from European settlers (Iorizzo et al. 2013). Current commercial materials are hybrid cultivars, developed using a cytoplasmic male sterility (CMS) system, a trait discovered in CWR (Alessandro et al. 2013). While we focus on North American wild relatives here, carrot has many non-North American relatives (31) that have a long history of breeding use. Carrots respond well to nitrogen applications and irrigation, but there is a need for advancing tolerances to abiotic stresses as the cultivated area increases. Major pests include carrot root fly, hoverflies, and leaf blight (Grzebelus et al. 2011). In carrot breeding, CWR have been an important source of resistance to these pests and helpful in overcoming other breeding limitations (Table 8.2). Ongoing characterization of genetic resources will continue to increase accessibility for breeders.

Table 8.2

Carrot crop wild relatives, genepool classification, and breeding use

Gene pool	Taxon	Native N.A. countries[a]	Breeding use	Number of accessions conserved in NPGS[b]	Number of accessions conserved in PGRC[c]	Number of accessions conserved in BGCI[d]	Number of accessions conserved in GENESYS[e]	Ex situ conservation status[f]	R

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex situ conservation status	R
Tertiary	*Daucus pusillus* Michx.	C, M, U	Gene transfer, sandy soil tolerance, soil salinity tolerance	37	NA	13	46	Well conserved	C et (2 2(

[a]Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

[b]USDA, ARS (2017)

[c]AFFC (2017)

[d]BGCI (2017)

[e]Global Crop Diversity Trust (2014) GENESYS

[f]Based on occurrence points relative to distribution maps and published literature

8.2.3. Conservation Status

Wild carrot species have long been a popular species for collection and utilization, both for food and medicinal purposes, in both North America and Europe (Banga 1957). The wild carrot species in North America is well conserved in ex situ germplasm collections. The most recent collecting trip by the USDA-ARS in 2010 resulted in the addition of 21 accessions of *D. pusillus* to the NPGS collection. This species has a large distribution and is represented across the southern and western United States, as well as western Canada; due to its broad presence, there are no specific concerns about its conservation status or current efforts to conserve it in situ.

8.3. Sweet Potato (*Ipomoea batatas* (L.) Lam.)

8.3.1. Introduction

Sweet potato (*Ipomoea batatas (L.) Lam.*) is one of the most important root crops in the world with 104 million metric tons produced in 2014 (FAO Stat 2014). Sweet potato is thought to have long been a staple in the human diet with archeological remains dating back 4,000 years (Solis et al. 2001). The crop also is highly nutritious and popular, being grown in over 100 countries (Khoury et al. 2015). The major constraints on production are viruses (SPVD) and insects (*Cylus* spp.), which can decrease yield between 60% and 100% (Khoury et al. 2015). Many of the close relatives of sweet potato show resistance to both biotic and abiotic stress (Table 8.3). Crossing relationships within *Ipomoea* are not well characterized; additionally, utilization is complicated by ploidy differences within and between species (Nimmakayala et al. 2011).

Table 8.3

Sweet potato’s crop wild relatives, genepool classification, and breeding use

Gene pool	Taxon	Native N.A. countries[a]	Breeding use	Number of accessions conserved in NPGS[b]	Number of accessions conserved in PGRC[c]	Number of accessions conserved in BGCI[d]	Number of accessions conserved in GENESYS[e]	E cons st
Secondary	*Ipomoea batatas* (L.) Lam. var. *apiculata* (Martens & Galeotti) McDonald & Austin	M	Drought tolerance	NA	NA	NA	NA	Poor cons
Secondary	*Ipomoea batatas* (L.) Poir	M	Drought tolerance; heat tolerance; waterlogging tolerance	NA	NA	NA	NA	Poor cons
Secondary	*Ipomoea littoralis* Blume	U	Drought tolerance; heat tolerance; sandy soil tolerance; waterlogging tolerance; dry matter yield; yield improvement; black rot resistance; scab resistance; weevil resistance	2	NA	1	2	Poor cons
Secondary	*Ipomoea tabascana* McDonald & Austin	M	Heat tolerance; waterlogging tolerance	1	NA	1	1	Poor cons

[a]Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

[b]USDA, ARS (2017)

[c]AFFC (2017)

[d]BGCI (2017)

[e]Global Crop Diversity Trust (2014) GENESYS

[f]Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	E cons st
Secondary	*Ipomoea trifida* (H.B.K.) G.Don.	M	Drought tolerance; heat tolerance; waterlogging tolerance; dry matter yield; yield improvement; black rot resistance; root knot nematode resistance; root lesion nematode resistance; scab resistance; weevil resistance; high starch content; protein content	46	NA	1	137	Mod cons
Tertiary	*Ipomoea cordatotriloba* Dennst. var. *cordatotriloba*	U	Cold tolerance; sandy soil tolerance	NA	NA	1	NA	Poor cons
Tertiary	*Ipomoea cordatotriloba* Dennst. var. *torreyana* (A. Gray) D. F. Austin	M, U	NA	NA	NA	NA	NA	Poor cons
Tertiary	*Ipomoea cordatotriloba* Dennstedt	M, U	NA	5	NA	6	34	Mod cons
Tertiary	*Ipomoea lacunosa* L.	U	Cold tolerance; drought tolerance; gene transfer	7	NA	3	8	Poor cons

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	E cons st
Tertiary	*Ipomoea leucantha* Jacquin	M, U	Drought tolerance; heat tolerance; sandy soil tolerance; gene transfer	NA	NA	NA	NA	Poor cons
Tertiary	*Ipomoea ramosissima* (Poiret) Choisy	M	Cold tolerance; waterlogging tolerance	4	NA	1	1	Poor cons
Tertiary	*Ipomoea splendor-sylvae* House	M	Drought tolerance; heat tolerance; waterlogging tolerance	1	NA	1	1	Poor cons
Tertiary	*Ipomoea tenuissima* Choisy	U	Cold tolerance; heat tolerance; sandy soil tolerance	1	NA	1	1	Poor cons
Tertiary	*Ipomoea tiliacea* (Willdenow) Choisy in D.C.	M	Heat tolerance; waterlogging tolerance	15	NA	2	16	Poor cons
Tertiary	*Ipomoea triloba* L.	M	Drought tolerance; heat tolerance; soluble sugar	36	NA	5	67	Mod cons

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

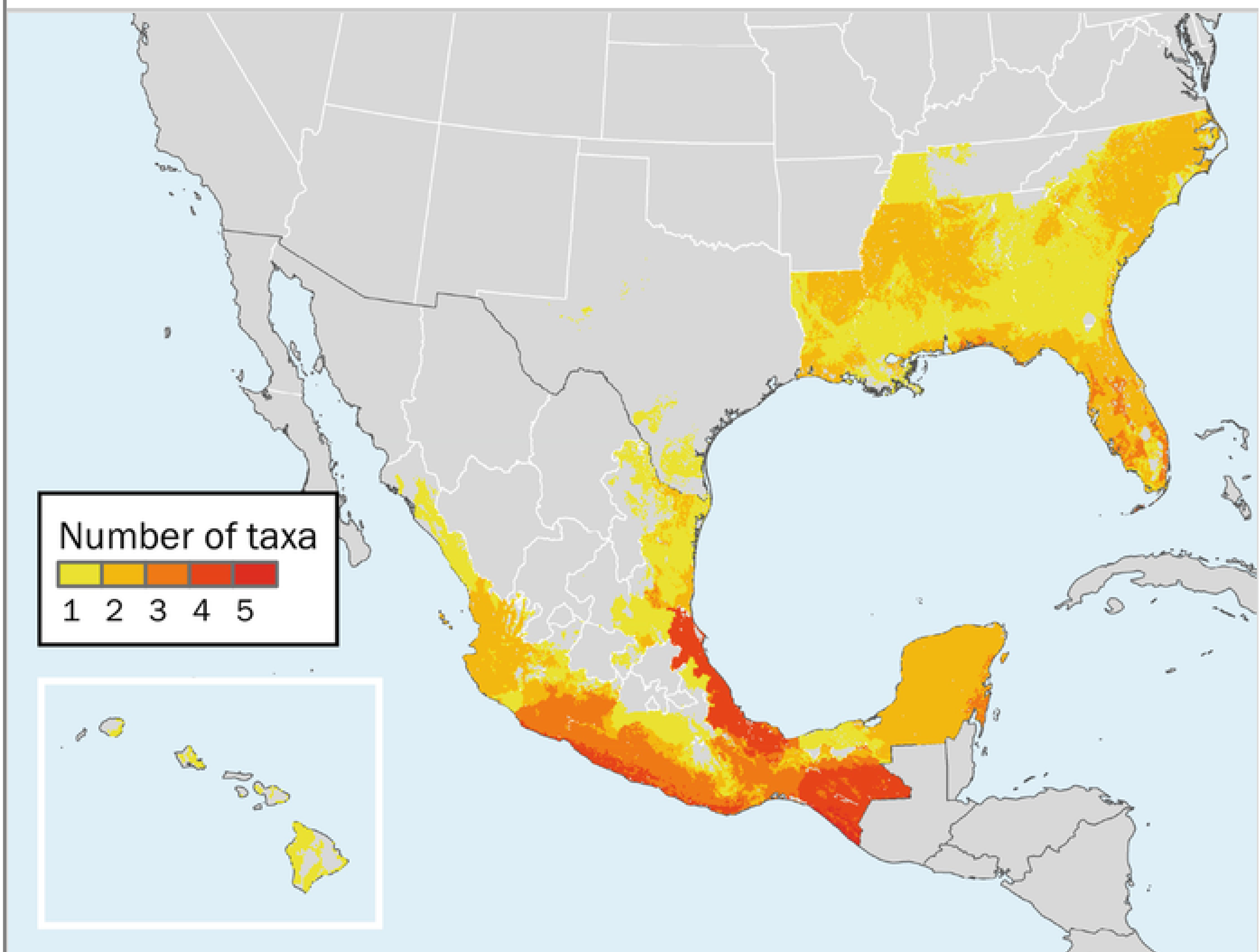
Based on occurrence points relative to distribution maps and published literature

8.3.2. Crop Wild Relatives and Wild Use

The genus *Ipomoea* contains ~500 species, and taxonomic relationships within *Ipomoea* remain unresolved, which is in part due to the large amount of interspecific hybridization. This implies that as new data are generated, the exact relationships of wild relatives to *Ipomoea* are likely to change. The CWR species present in North America include *I. lacunose* L., *I. leucantha* Jacq., *I. tenuissima* Choisy, *I. cordatotriloba* Dennst., *I. tiliacea* (Willd.) Choisy, *I. splendor-sylvae* House, and *I. trifida* (Kunth) G.Don (Table 8.3; Fig. 8.1). These species occupy ecological niches that may provide adaptation to diverse biotic and abiotic stresses (Table 8.3). There has been a history of eating many of the different wild sweet potato species, as well as using them for medicinal purposes (Austin and Huáman 1996; Pío-León et al. 2017~~2016~~).

Fig. 8.1

Species richness map of modeled potential distributions of North American *Ipomoea* taxa, based on climatic and edaphic similarities with herbarium and genebank reference localities. Warmer colors indicate areas where greater numbers of taxa potentially occur in the same geographic localities. Full methods for generation of maps and data providers are given in Appendix 1



8.3.3. Conservation Status

The major challenge to using the CWR is the limited number of accessions available in ex situ collections. Recent work has identified that 70% of the CWR of sweet potato have only limited numbers of individuals currently preserved in ex situ collections and therefore are in great need of further collection (Khoury et al.

2015). Currently, there are only 749 germplasm accessions available in germplasm banks (Khoury et al. 2015). Increasing the number of accessions available and the creation of genetic stocks that contain introgressions from wild relatives at the correct ploidy level could prove valuable to ongoing breeding efforts. Due to the difficulty and expense in conservation, the CWR of sweet potato have lagged behind those of other crops in availability.

There is a great need to conserve the wild relatives, especially as the specialty markets of sweet potato increase in value. Several members of the *Ipomoea* genus are listed by NatureServe as vulnerable (*I. tenuissima* Choisy, *I. thurberi* A. Gray, *I. plummerae var. cuneifolia* (Gray) MacBride) or imperiled (*I. tuboides* O. Deg. & van Ooststr., *I. shumardiana* (Torr.) Shinners, *I. microdactyla* Griseb.) in their native ranges across North America (www.natureserve.org; NatureServe 2017); however of these, only *I. tenuissima* has a known breeding use.

8.4. Potato (*Solanum tuberosum* L.)

8.4.1. Introduction

Potato (*Solanum tuberosum* L.) is the fourth most widely produced crop in the world by yield and the most widely produced tuber (Ramsay and Bryan 2011). In 2014, 385 million metric tons were produced (FAO Stat 2014). Potato underwent a single domestication event in the Andean mountain range in Peru from the *Solanum bukasovii* Juz. species complex around 8,000 years ago (Spooner et al. 2005; Ramsay and Bryan 2011). There are a multitude of CWR in potato (Table 8.4), many of which have valuable resistance to the limiting factors to modern potato production, including diseases (e.g., blight, bacterial wilt, verticillium wilt), pests (potato beetle), and abiotic stress (Srivastava et al. 2016). These diverse CWR have been extensively used in potato improvement (Table 8.4), despite limitations of ploidy differences and different endosperm balance numbers. There is a long history of many different wild potato species being consumed, with many different species having specific uses (Ladio 2001).

Table 8.4

Potato's crop wild relatives, genepool classification, and use in potato breeding

Gene pool	Taxon	Native N.A. countries[a]	Breeding use	Number of accessions conserved in NPGS[b]	Number of accessions conserved in PGRC[c]	Number of accessions conserved in BGCI[d]	Number of accessions conserved in GENESYS[e]	Ex s conser stat
Secondary	*Solanum agrimonifolium* Rydb.	M	NA	NA	NA	NA	NA	Poorly conserv
Secondary	*Solanum clarum* Correll	M	NA	14	NA	1	18	Poorly conserv

[a]Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

[b]USDA, ARS (2017)

[c]AFFC (2017)

[d]BGCI (2017)

[e]Global Crop Diversity Trust (2014) GENESYS

[f]Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex s conser stat
Secondary	*Solanum demissum* Lindl.	M	Blackleg and soft rot resistance, potato leaf roll virus resistance, late blight resistance, Colorado potato beetle resistance, cyst nematode resistance, frost tolerance, potato virus Y resistance, wart resistance	164	NA	2	665	Well conser
Secondary	*Solanum guerreroense* Correll	M	Spindle tuber viroid resistance	2	NA	1	14	Well conser
Secondary	*Solanum hintonii* Correll	M	NA	1	NA	1	2	Poorly conser
Secondary	*Solanum hjertingii* Hawkes	M	Blackleg and soft rot resistance, root knot nematode resistance, spindle tuber viroid resistance	13	NA	1	6	Poorly conser

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex s conser stat
Secondary	*Solanum hougasii* Correll	M	Root knot nematode resistance, potato virus Y resistance, late blight resistance	10	NA	1	116	Poorly conserv
Secondary	*Solanum iopetalum* (Bitter) Hawkes	M	Late blight resistance	60	NA	1	NA	Modera conserv
Secondary	*Solanum lesteri* Hawkes & Hjert.	M	NA	3	NA	2	NA	Modera conserv
Secondary	*Solanum morelliforme* Bitter & Munch	M	NA	20	NA	1	6	Modera conserv
Secondary	*Solanum oxycarpum* Schiede	M	NA	20	NA	1	NA	Modera conserv
Secondary	*Solanum polyadenium* Greenmam	M	Colorado potato beetle resistance, Late blight resistance	18	4	3	6	Modera conserv
Secondary	*Solanum schenckii* Bitter	M	NA	15	NA	1	2	Modera conserv

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex s conser stat
Secondary	*Solanum stoloniferum* Schltdl. & Bouche	M, U	Late blight resistance, potato virus Y resistance, aphid resistance, drought tolerance, heat tolerance, potato leaf roll virus resistance	485	1	3	2	Well conser
Secondary	*Solanum verrucosum* Schltdl.	M	Late blight resistance	46	NA	2	4	Moder conser
Tertiary	*Solanum bulbocastanum* Dunal	M	Blackleg and soft rot resistance, late blight resistance, root knot nematode resistance, aphid resistance, cyst nematode resistance, drought tolerance, early blight resistance, heat tolerance	56	NA	1	161	Well conser

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex s conser stat
Tertiary	*Solanum cardiophyllum* Lindl.	M	Late blight resistance, root knot nematode resistance, cyst nematode resistance	11	NA	2	78	Modera conserv
Tertiary	*Solanum ehrenbergii* (Bitter) Rydb.	M	NA	28	NA	1	38	
Tertiary	*Solanum jamesii* Torr.	M, U	Colorado potato beetle resistance, common scab resistance	165	NA	1	82	Well conserv
Tertiary	*Solanum pinnatisectum* Dunal	M	Blackleg and soft rot resistance, chip making from cold, Colorado potato beetle resistance, drought tolerance, heat tolerance, late blight resistance	19	NA	1	NA	Modera conserv
Tertiary	*Solanum stenophyllidium* Bitter	M	Frost tolerance	25	NA	2	4	Modera conserv

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex s conser stat
Tertiary	*Solanum tarnii* Hawkes & Hjert.	M	Colorado potato beetle resistance, late blight resistance, potato virus X resistance	11	NA	1	2	Poorly conserv
Tertiary	*Solanum trifidum* Correll	M	NA	14	NA	1	24	Modera conserv

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

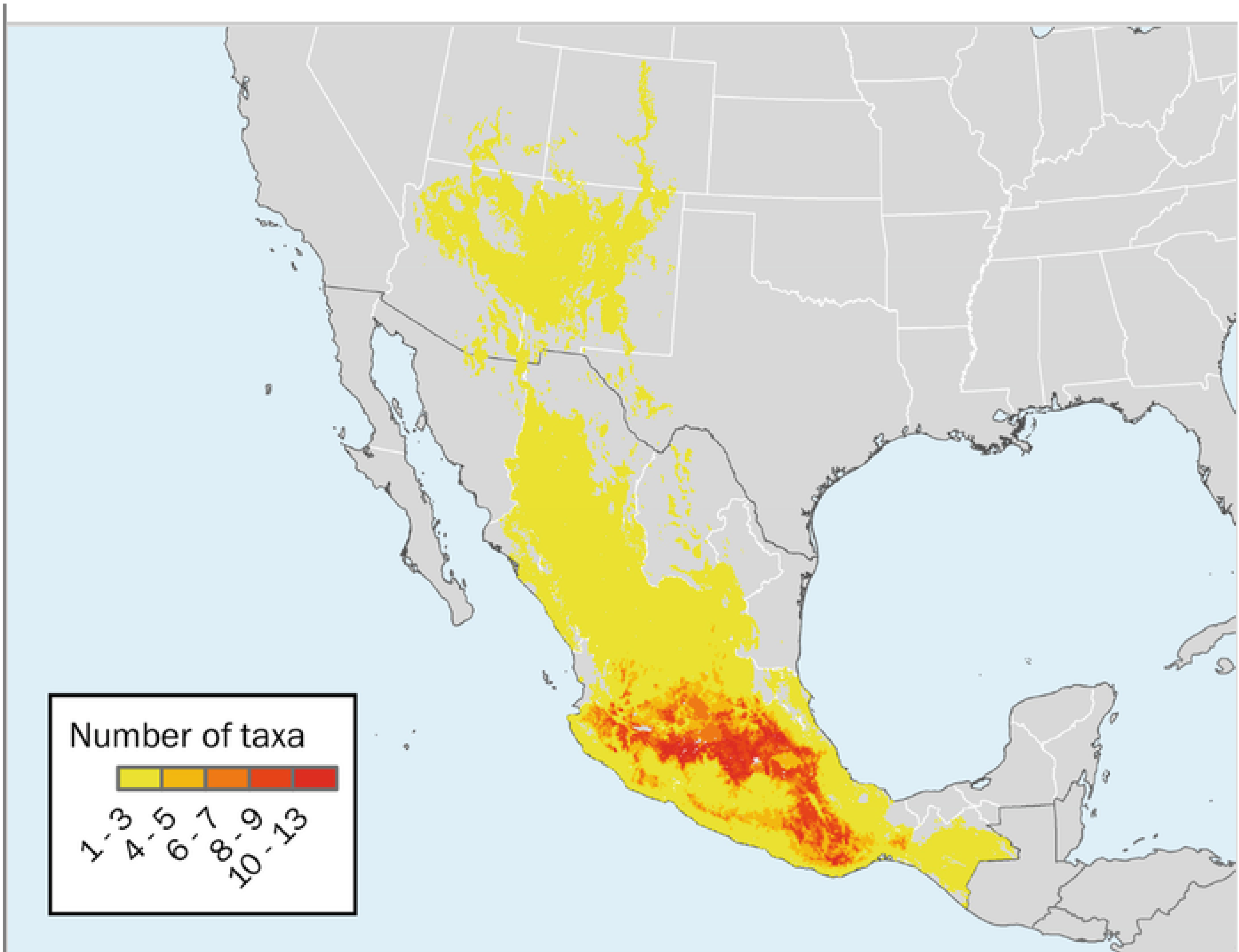
Based on occurrence points relative to distribution maps and published literature

8.4.2. Crop Wild Relatives and Wild Use

A recent examination of accessions of *Solanum* wild relatives in germplasm repositories found many species are in high need of further collection, including four native to North America: *S. clarum* Correll, *S. hintonii* Correll, *S. hjertingii* Hawkes, and *S. hougasii* Correll (Castañeda-Álvarez et al. 2015). Several species were further identified as having a moderate need for collection, including the North American species: *S. iopetalum* (Bitter) Hawkes, *S. lesteri* Hawkes & Hjert, *S. morelliforme* Bitter & Muench, *S. oxycarpum* Schiede, *S. polyadenium* Greenmam, *S. schenckii* Bitter, *S. tarnii* Hawkes & Hjert, and *S. verrucosum* Schltdl (Castañeda-Álvarez et al. 2015). Unfortunately, several of these same CWR are threatened by habitat destruction and climate change (Fig. 8.2). It is becoming increasingly important to conserve the species underrepresented in genebanks that are being impacted in their native habitats. Despite potato's economic importance and long history of CWR use, many of the CWR have not been evaluated for beneficial traits. Advances in pre-breeding, improved cisgenic techniques, and new genotyping and phenotyping methods will help to continue to unlock the agronomic potential found within these wild relatives, making their conservation ex situ more useful and efficient (Castañeda-Álvarez et al. 2015).

Fig. 8.2

Species richness map of modeled potential distributions of North American *Solanum* taxa, based on climatic and edaphic similarities with herbarium and genebank reference localities. Warmer colors indicate areas where greater numbers of taxa potentially occur in the same geographic localities. Full methods for generation of maps and data providers are given in Appendix 1



8.4.3. Conservation Status

The coverage of wild potato in ex situ collections is uneven, and better characterization of the many different potato species is needed. There have been extensive efforts to collect *Solanum* species in the United States; these collection efforts were led by the USDA-ARS and have focused on *Solanum jamesii* (jam) and *S. fendleri* (fen) (Bamberg et al. 2016). There is only one member of the genus that is listed as of in situ conservation concern by NatureServe; *S. jamesii* is ranked as vulnerable (www.natureserve.org; NatureServe 2017).

8.5. Jerusalem Artichoke (*Helianthus tuberosus* L.)

8.5.1. Introduction

Jerusalem artichoke, the domesticated form of *Helianthus tuberosus* L., shows reduced tuber number and increased individual tuber size relative to wild collected individuals. *Helianthus tuberosus* is native to central North America (Kays and Nottingham 2008; Rogers et al. 1982) and was domesticated in the eastern United States. *Helianthus tuberosus* is an autoallohexaploid whose progenitors are likely the autotetraploid *H. hirsutus* Raf. (an autotetraploid of *H. divaricatus* L.) and the diploid *H. grosseserratus* Martens (Bock et al. 2014). Wild sunflowers have been collected for medicinal and food purposes since prehistory; the most common species to collect and eat are wild *H. tuberosus* and wild *H. annuus* L. (Kays and Nottingham 2008). Little is known about the extent of cultivation in North America prior to European contact due to a limited fossil record. The crop was introduced to the royal court of France in the seventeenth century and soon became a favorite of the European aristocracy (Kays and Nottingham 2008). Cultivation guides were published as early as the mid-eighteenth century (Brookes 1763), and production continued to increase until the potato largely replaced *Helianthus tuberosus* in diets. The crop is grown as a winter or summer annual. There has been little intentional interspecific introgression into domesticated *H. tuberosus*.

Helianthus tuberosus is widely resistant to both insect pathogens and diseases and has often been used as a donor species in *Helianthus annuus* (sunflower) breeding (Kantar et al. 2014). *Helianthus tuberosus* is also salt and drought tolerant and easily grown in coastal arid and semiarid areas (Ma et al. 2011) and has been used to improve soil and water conservation in desertified areas (Cheng et al. 2009). The native range of *Helianthus tuberosus* is quite large, ranging from the Mississippi River to the Atlantic Ocean and from the Gulf of Mexico to the Hudson Bay (Kantar et al. 2015). The large range provides many opportunities to find populations that are adapted to diverse climatic and biological stresses. When cultivated, *H. tuberosus* is planted using tuber parts and replanted every 3 years (Kays and Nottingham, 2008~~Kays et al. 2008~~). A major limitation to production is that the species can become a volunteer weed in subsequent crops.

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8.5.2. Crop Wild Relatives and Wild Use

Crop wild relatives within *Helianthus* have generally been defined with respect to *Helianthus annuus*, rather than *Helianthus tuberosus*, and are found throughout North America (Fig. 8.3). Despite this, the large species range of *Helianthus tuberosus*, the large number of species in the genus, and the large amount of hybridization within the genus make half of the species in the genus available for hybridization (Table 8.5). The major difficulty with the utilization of other *Helianthus* species is the difference in ploidy; this causes extra generations to be necessary in order to generate useful breeding material. The crop has excellent nutritional properties (Kays and Nottingham 2008), industrial applications (rubber; Seiler et al. 1991a, b, biofuel; Seiler and Campbell 2006), medicinal uses (diabetes treatment; Kays and Nottingham 2008), and forage potential (Seiler and Campbell 2004).

Fig. 8.3

Species richness map of modeled potential distributions of North American *Helianthus* taxa, based on climatic and edaphic similarities with herbarium and genebank reference localities. Warmer colors indicate areas where greater numbers of taxa potentially occur in the same geographic localities. Full methods for generation of maps and data providers are given in Appendix 1

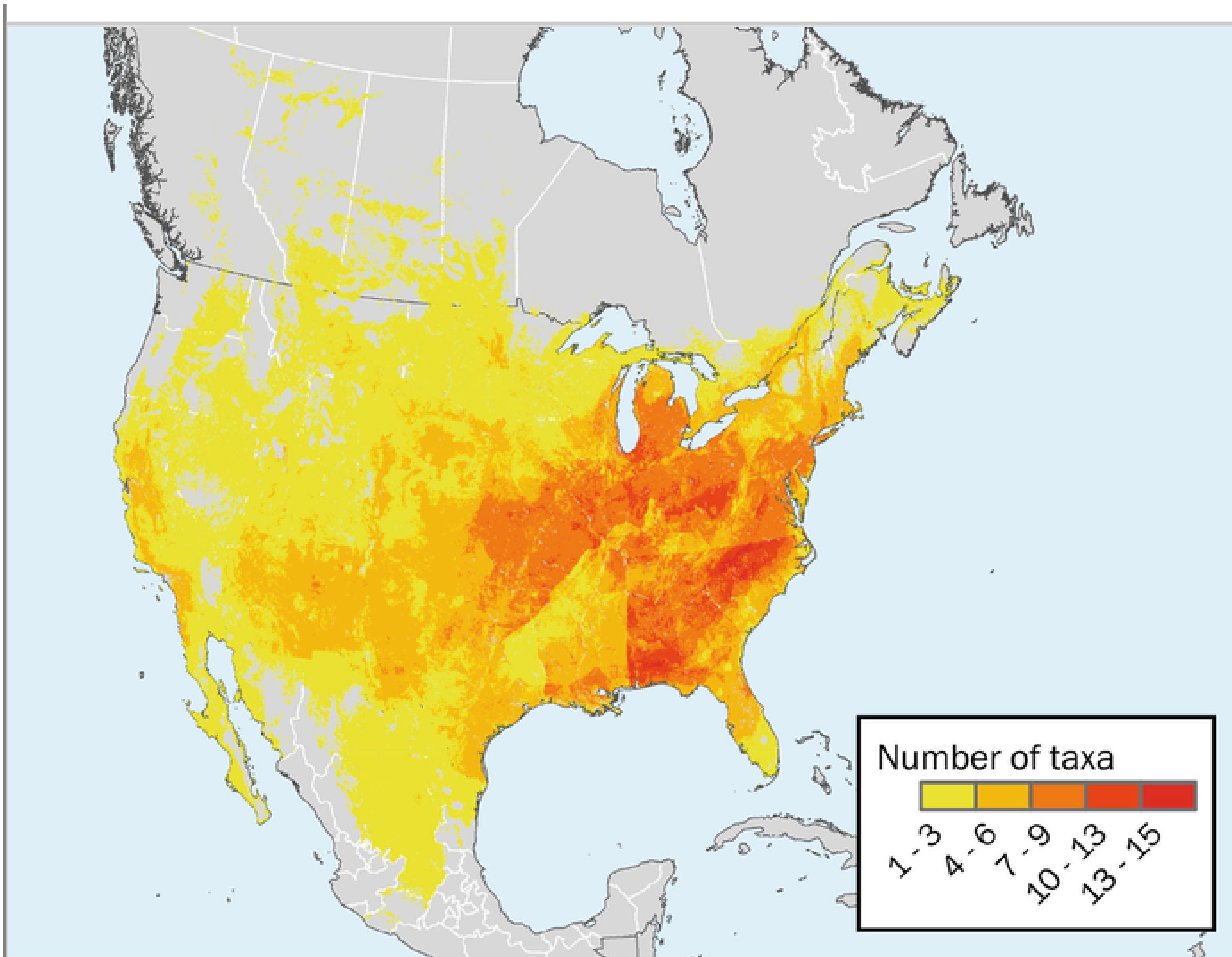

Table 8.5

Crop wild relatives of *H. tuberosus* and potential breeding uses (the potential breeding uses of CWR are not well defined diversity both in ecological niche and biotic stress that is already present in *H. tuberosus*)

Gene pool	Taxon	Native N.A. countries[a]	Breeding use	Number of accessions conserved in NPGS[b]	Number of accessions conserved in PGRC[c]	Number of accessions conserved in BGCI[d]	Number of accessions conserved in GENESYS[e]	E: cons st

[a]Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

[b]USDA, ARS (2017)

[c]AFFC (2017)

[d]BGCI (2017)

[e]Global Crop Diversity Trust (2014) GENESYS

[f]Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex conse st
Secondary	*H. annuus L.*	C, M, U	Pest, disease resistance, salt tolerance, drought tolerance, herbicide tolerance	3656	655	96	8539	Well conse
Secondary	*H. anomalus Blake*	U	NA	16	NA	3	12	Poorl conse
Secondary	*H. argophyllus Torr. & Gray*	U	Downy mildew resistance, disease resistance, salt tolerance, drought tolerance	79	NA	9	94	Mode conse
Tertiary	*H. arizonensis Jackson*	U	NA	2	NA	1	5	Mode conse
Tertiary	*H. atrorubens* L.	U	NA	12	NA	17	19	Mode conse
Secondary	*H. bolanderi* A. Gray	U	NA	14	NA	4	20	Poorl conse

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	E: cons st
Secondary	*H. debilis* subsp. *cucmerifolius (Torrey & A. Gray*	U	NA	14	NA	NA	11	Poorl conse
Secondary	*H. debilis* subsp. *debilis Nutt.*	U	Powdery mildew resistance	13	NA	NA	12	Mode conse
Secondary	*H. debilis* subsp. *silvestris Heiser*	U	NA	22	NA	NA	24	Mode conse
Secondary	*H. debilis* subsp. *tardiflorus Heiser*	U	Resistance to broomrape	13	NA	NA	9	Well conse
Secondary	*H. debilis* subsp. *vestitus Heiser*	U	NA	11	NA	NA	3	Well conse
Secondary	*H. deserticola Heiser*	U	Downy mildew resistance	24	NA	1	24	Poorl conse
Primary	*H. divaricatus* L.	C, U	Broomrape resistance	21	NA	30	50	Poorl conse
Secondary	*H. exilis* A. Gray	U	NA	30	NA	1	41	Mode conse
Tertiary	*H. giganteus* L.	C, U	NA	26	NA	33	42	Poorl conse
Primary	*H. grosseserratus Martens*	U	Broomrape resistance	46	NA	21	69	Mode conse
Primary	*H. hirsutus* Raf.	C, M, U	NA	14	NA	18	26	Poorl conse

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex cons st
Tertiary	*H. maximiliani* Schrader	C, U	Broomrape resistance	68	3	27	84	Mode conse
Secondary	*H. neglectus* Heiser	U	NA	40	NA	1	41	Well conse
Secondary	*H. niveus* subsp. *canescens* A. Gray	M, U	NA	20	NA	NA	22	Poorl conse
Secondary	*H. niveus* subsp. *niveus* Benth.	M	NA	1	NA	5	14	Poorl conse
Secondary	*H. niveus* subsp. *tephrodes Heiser*	M, U	NA	11	NA	NA	11	Poorl conse
Secondary	*H. paradoxus* Heiser	U	Salt tolerance	13	NA	3	20	Well conse
Tertiary	*H. pauciflorus* subsp. *pauciflorus* Nutt	C, U	Sclerotinia resistance	21	NA	NA	21	Poorl conse
Tertiary	*H. pauciflorus* subsp. *subrhomboideus* Nutt	C, U	NA	17	NA	NA	18	Poorl conse
Secondary	*H. petiolaris* subsp. *fallax* Heiser	U	NA	61	NA	NA	31	Poorl conse

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex conse st
Secondary	*H. petiolaris* subsp. *petiolaris* Nutt.	C, U	Verticillium resistance; disease resistance; sunflower moth resistance	126	NA	NA	107	Well conse
Secondary	*H. praecox* subsp. *hirtus* Heiser	U	NA	7	NA	NA	8	Well conse
Secondary	*H. praecox* subsp. *praecox* A. Gray	U	Downy mildew, rust, verticillium wilt and broomrape resistance; downy mildew resistance	8	NA	NA	10	Well conse
Secondary	*H. praecox* subsp. *runyonii* Heiser	U	NA	26	NA	NA	27	Well conse
Secondary	*H. resinosus*	U	NA	23	NA	5	34	Mode conse
Tertiary	*H. salicifolius A. Dietr*	U	NA	19	NA	52	27	Mode conse
Tertiary	*H. silphioides* Nutt.	U	NA	15	NA	2	16	Well conse
Tertiary	*H. strumosus* L.	C, U	NA	29	NA	33	46	Poorl conse

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	E[x situ] cons[ervation] st[atus]
Secondary	*H. winteri* Stebbins	U	NA	NA	NA	NA	NA	Poorl[y] cons[erved]
Primary	*Helianthus tuberosus (wild)*	C, U	Broomrape resistance; sunflower moth resistance	91	7	106	331	Mode[rately] cons[erved]

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

8.5.3. Conservation Status

Conservation priorities differ across the genus, with ~75% of the species needing further collection for ex situ conservation (Kantar et al. 2015). There are several species that are at risk including *Helianthus paradoxus* Heiser, which is ranked threatened by the US Fish and Wildlife Service (ECOS 2016) and imperiled by NatureServe (www.natureserve.org; NatureServe 2017). *Helianthus neglectus* Heiser is ranked imperiled, and *Helianthus winteri* Stebbins is ranked critically imperiled by NatureServe (2017; www.natureserve.org). There are several species that are ranked vulnerable by NatureServe, including *H. anomalus* Blake, *H. debilis* spp. *tardiflorus* Heiser, and *H. debilis* spp. *vestitus* Heiser (www.natureserve.org; NatureServe 2017).

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8.6. Jicama (*Pachyrhizus erosus* (L.) Urb.)

8.6.1. Introduction

Jicama (*Pachyrhizus erosus* (L.) Urb.) is a tropical short day legume that is grown mostly in warm humid environments with intermediate levels of rainfall (Lim 2016). Indigenous to Mexico and Central America, jicama is now broadly grown across the tropics and neotropics (Reddy 2015). Other crops in the *Pachyrhizus* genus include ahipa (*Pachyrhizus ahipa* (Wedd.) Parodi) and Amazonian yam bean (*Pachyrhizus tuberosus* (Lam.) Spreng.) (USDA, ARS 2017). Worldwide, jicama is a minor crop, but locally it is favored as part of many different types of cuisine. Generally, the plant takes approximately 6 months from planting to tuber harvest (Reddy 2015). Tubers can be eaten raw or cooked, having similar food value to potatoes; the immature seedpods can also be eaten, but the mature seeds are not consumed (Lim 2016). There are many different pests that impact crop production, including leafhopper, whiteflies, mealy bug, thrips, termites, coffee bean weevil, and pod borer (Reddy 2015). The most damaging diseases are rust and sincama mosaic virus (Reddy 2015). For acreage to increase, improved agronomic traits and pest tolerance are needed.

8.6.2. Crop Wild Relatives and Wild Use

There is very limited data on CWR breeding uses due to the semidomesticated nature of the crop (Table 8.6). This lack of knowledge has led to lagging conservation efforts for the important wild relatives. However, since antiquity wild jicama has been collected and used as a crop (Bronson 1966), and recently it has increased in use as a specialty crop.

Table 8.6

Crops of the *Pachyrhizus* genus and their crop wild relatives, genepool classification, and breeding uses

Gene pool	Taxon	Native N.A. countries[a]	Breeding use	Number of accessions conserved in NPGS[b]	Number of accessions conserved in PGRC[c]	Number of accessions conserved in BGCI[d]	Number of accessions conserved in GENESYS[e]	Ex sit conserva status
Jicama/yam bean *Pachyrhizus erosus* (L.) Urb.	Primary	*Pachyrhizus erosus* (L.) Urb.	M	NA	7	NA	16	84
	Secondary	*Pachyrhizus ferrugineus* (Piper) M. Sorensen	M	NA	NA	NA	NA	1
	Secondary	*Pachyrhizus sp.*	M	NA	3	NA	NA	23

[a]Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

[b]USDA, ARS (2017)

[c]AFFC (2017)

[d]BGCI (2017)

[e]Global Crop Diversity Trust (2014) GENESYS

[f]Based on occurrence points relative to distribution maps and published literature

8.6.3. Conservation Status

In general, there is a need to increase the conservation of wild relatives of this species. Only one of the wild relatives is even moderately well conserved in ex situ germplasm collections, with the other species being poorly conserved (Table 8.6). These species have not been well explored for in situ vulnerability.

8.7. Cocoyam, Tannia, Yautia (*Xanthosoma sagittifolium (L.) Schott)*

8.7.1. Introduction

Cocoyam, tannia, and yautia are a few of the many synonymous names for the edible aroid crop *Xanthosoma sagittifolium* (L.) Schott grown in many tropical regions (Reddy 2015). Originating in the northern Amazon Basin in South America, this crop is now widely cultivated around the tropics (Quero-Garcia et al. 2010). Brought to Europe and Africa multiple times during the sixteenth and seventeenth centuries, it eventually was transported to Asia and Oceania by the nineteenth century (Quero-Garcia et al. 2010). Cocoyam is often used as food when other sources of calories are unavailable. The traits important for cultivars include corm shape, plant architecture, plant size, corm color, and leaf color. Most of the cultivars are local heirloom types. One major limitation to production is cocoyam root rot disease; identifying resistance to this pathogen is the primary breeding objective (Reddy 2015). Currently there are a limited number of breeding programs, and breeding efforts have yet to see much success, possibly due to ploidy differences. In Cameroon, where cocoyam improvements were initiated, few viable seeds were produced (Tambong et al. 1997; Onokpise et al. 1999). DNA markers have been used to study cocoyam diversity; however, the genetic dissimilarity between the accessions was low, and the existing ex situ collection was deemed of limited value as a genetic resource (Quero-Garcia et al. 2010).

8.7.2. Crop Wild Relatives and Wild Use

Current understanding of the cocoyam genepool is limited to knowledge of species within the *Xanthosoma* genus (Table 8.7). Phenotypic characterization of current and newly collected accessions could prove most helpful for ongoing plant breeding. While cocoyam is an old crop (Bronson 1966), it is not frequently grown on a large scale; this has led to extensive wild crafting and use of different species interchangeably.

Table 8.7

Cocoyam, tannia, or yautia (*Xanthosoma sagittifolium*) crop wild relatives, genepool classification, and breeding use

Gene pool	Taxon	Native N.A. countries[a]	Breeding use	Number of accessions conserved in NPGS[b]	Number of accessions conserved in PGRC[c]	Number of accessions conserved in BGCI[d]	Number of accessions conserved in GENESYS[e]	Ex situ conservati status[f]
Undefined	*Xanthosoma mexicanum* Liebm.	M	NA	NA	NA	4	1	Poorly conserved
Undefined	*Xanthosoma narinoense* Bogner & L. P. Hannon	M	NA	NA	NA	NA	NA	Poorly conserved
Undefined	*Xanthosoma obtusilobum* Engl.	M	NA	NA	NA	NA	NA	Poorly conserved
Undefined	*Xanthosoma robustum* Schott	M	NA	NA	NA	21	5	Poorly conserved

[a]Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

[b]USDA, ARS (2017)

[c]AFFC (2017)

[d]BGCI (2017)

[e]Global Crop Diversity Trust (2014) GENESYS

[f]Based on occurrence points relative to distribution maps and published literature

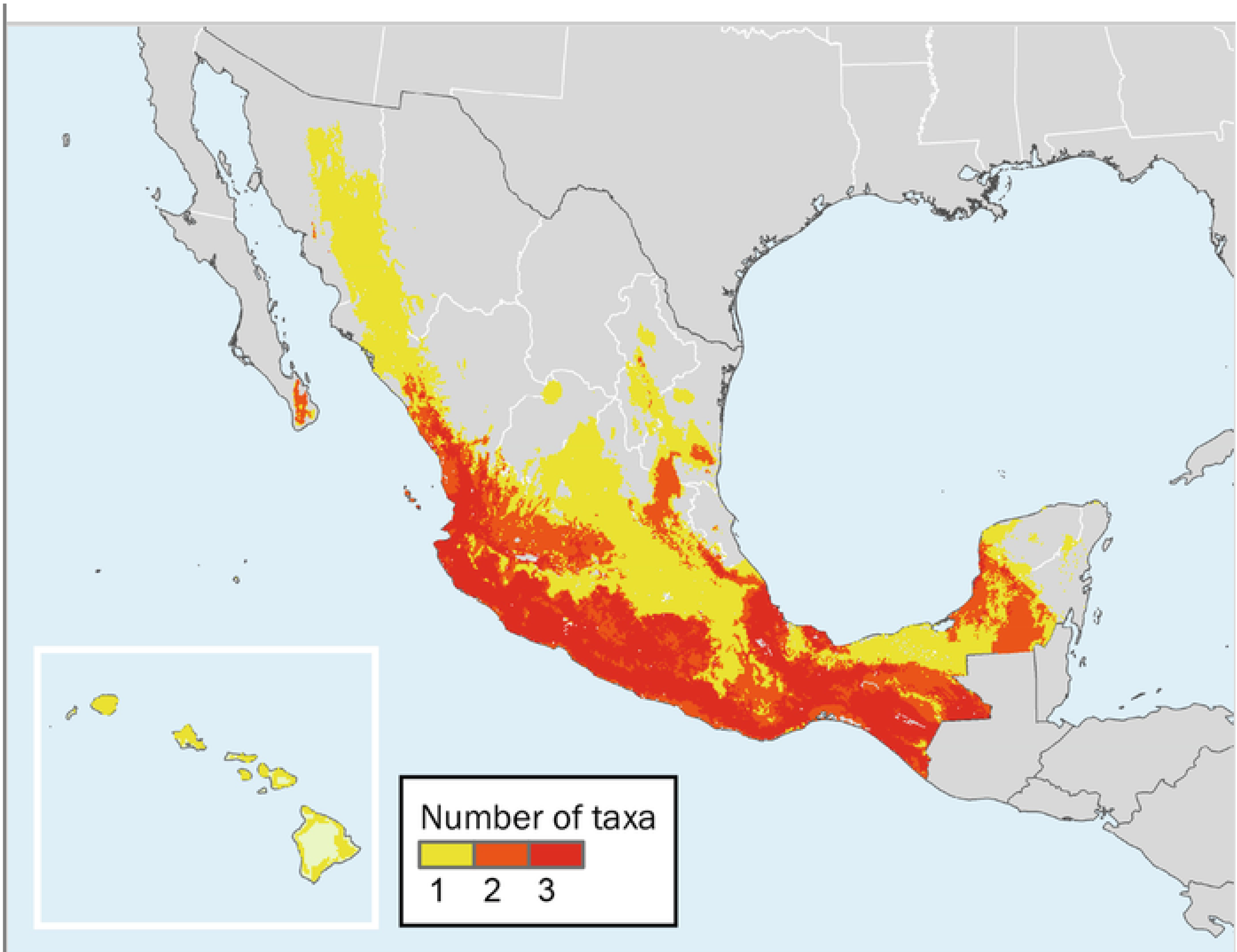
Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex situ conservati status
Undefined	*Xanthosoma wendlandii* (Schott) Standl.	M	NA	NA	NA	2	NA	Poorly conserved
Undefined	*Xanthosoma yucatanense* Engl.	M	NA	NA	NA	NA	NA	Poorly conserved
Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)								
USDA, ARS (2017)								
AFFC (2017)								
BGCI (2017)								
Global Crop Diversity Trust (2014) GENESYS								
Based on occurrence points relative to distribution maps and published literature								

8.7.3. Conservation Status

Xanthosoma requires extensive collection; this group of species is very understudied despite a wide distribution across Mexico (Fig. 8.4). It is necessary to define many of the basic species relationships as well as how they can be used to improve cultivars. *Xanthosoma* species are either not well explored or secure in situ.

Fig. 8.4

Species richness map of modeled potential distributions of North American *Xanthosoma* taxa, based on climatic and edaphic similarities with herbarium and genebank reference localities. Warmer colors indicate areas where greater numbers of taxa potentially occur in the same geographic localities. Full methods for generation of maps and data providers are given in Appendix 1



8.8. Cassava (*Manihot esculenta* Crantz)

8.8.1. Introduction

Cassava (*Manihot esculenta* Crantz) is widely cultivated in the tropics, currently providing the third highest number of calories after maize and rice (FAO Stat 2014). Cassava contains many valuable introgressions from wild relatives as there are few crossing barriers within the *Manihot* genus (Table 8.8). Cassava was domesticated ~5000 years ago in the American Tropics (Piperno and Holst 1998). There still remains debate over the precise geographic origin and if there was a single or multiple domestications (Bradbury et al. 2013; Olsen and Schaal. 1999). The oldest archeological evidence of cassava cultivation dates to 7000 years ago in the Andean and Caribbean regions (Piperno et al. 2000). Cassava was brought to Europe in the sixteenth century and made its way to Asia and Africa by the eighteenth century (Onwueme 2002). Although it is known for its good general drought tolerance and growth in low-nutrient environments, there are many problems that can decrease yields, including cassava mosaic virus, bacterial blight, and brown streak disease (Narina et al. 2011). Viruses can also impact propagation through affecting cuttings used for planting reducing vigor and therefore yield potential. There is limited use of wild relatives directly as food due to the presence of poisonous compounds (Nassar 1978).

Table 8.8

Cassava’s crop wild relatives, genepool classification, and use in cassava breeding

Gene pool	Taxon	Native N.A. countries[a]	Breeding use	Number of accessions conserved in NPGS[b]	Number of accessions conserved in PGRC[c]	Number of accessions conserved in BGCI[d]	Number of accessions conserved in GENESYS[e]	Ex conser stat
Secondary	*Manihot foetida* (Kunth) Pohl	M	NA	NA	NA	1	NA	Poorly conser
Tertiary	*Manihot aesculifolia* Pohl	M	Robustness	NA	NA	1	NA	Poorly conser
Tertiary	*Manihot angustiloba* (Torr.) Müll. Arg.	M, U	Drought tolerance; gene transfer	NA	NA	1	NA	Poorly conser
Tertiary	*Manihot auriculata* McVaugh	M	NA	NA	NA	NA	NA	Poorly conser
Tertiary	*Manihot caudata* Greenm.	M	NA	NA	NA	3	NA	Poorly conser
Tertiary	*Manihot chlorosticta* Standl. & Goldman	M	Soil salinity tolerance	NA	NA	NA	5	Poorly conser
Tertiary	*Manihot crassisepala* Pax & K. Hoffm.	M	NA	NA	NA	NA	NA	Poorly conser
Tertiary	*Manihot davisiae* Croizat	M, U	Drought tolerance	NA	NA	1	NA	Poorly conser
Tertiary	*Manihot mcvaughii* Steinmann	M	NA	NA	NA	NA	NA	Poorly conser
Tertiary	*Manihot michaelis* McVaugh	M	NA	NA	NA	NA	NA	Poorly conser

[a]Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

[b]USDA, ARS (2017)

[c]AFFC (2017)

[d]BGCI (2017)

[e]Global Crop Diversity Trust (2014) GENESYS

[f]Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex conser stat
Tertiary	*Manihot oaxacana* D. J. Rogers & Appan	M	NA	NA	NA	NA	NA	Poorly conser
Tertiary	*Manihot obovata* J. Jimenez Ram.	M	NA	NA	NA	NA	NA	Poorly conser
Tertiary	*Manihot pauciflora* Brandegee	M	NA	NA	NA	1	2	Poorly conser
Tertiary	*Manihot pringlei* S. Watson	M	Low cyanide content	NA	NA	NA	NA	Poorly conser
Tertiary	*Manihot rhomboidea* Müll. Arg.	M	NA	NA	NA	1	NA	Poorly conser
Tertiary	*Manihot rhomboidea* Müll. Arg. subsp. *microcarpa* (Müll. Arg.) D. J. Rogers & Appan	M	NA	NA	NA	NA	1	Poorly conser
Tertiary	*Manihot rhomboidea* Müll. Arg. subsp. *rhomboidea* Müll. Arg.	M	NA	NA	NA	1	NA	Poorly conser
Tertiary	*Manihot rubricaulis* I. M. Johnst. subsp. *isoloba* (Standl.) D. J. Rogers & Appan	M	NA	NA	NA	NA	1	Poorly conser

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

Based on occurrence points relative to distribution maps and published literature

Gene pool	Taxon	Native N.A. countries	Breeding use	Number of accessions conserved in NPGS	Number of accessions conserved in PGRC	Number of accessions conserved in BGCI	Number of accessions conserved in GENESYS	Ex conser stat
Tertiary	*Manihot rubricaulis* I. M. Johnst. subsp. *rubricaulis* I. M. Johnst.	M	NA	NA	NA	NA	NA	Poorly conser
Tertiary	*Manihot rubricaulis* I. M. Johnst.	M	Cold tolerance	NA	NA	NA	1	Poorly conser
Tertiary	*Manihot subspicata* D. J. Rogers & Appan	M	NA	NA	NA	NA	NA	Poorly conser
Tertiary	*Manihot tomatophylla* Standl.	M	NA	NA	NA	NA	NA	Poorly conser
Tertiary	*Manihot triloba* (Sessé ex Cerv.) Miranda	M	NA	NA	NA	1	NA	Poorly conser
Tertiary	*Manihot walkerae* Croizat	M, U	Postharvest physiological deterioration tolerance	NA	NA	3	NA	Poorly conser
Tertiary	*Manihot websteri* D. J. Rogers & Appan	M	NA	NA	NA	NA	NA	Poorly conser

Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

USDA, ARS (2017)

AFFC (2017)

BGCI (2017)

Global Crop Diversity Trust (2014) GENESYS

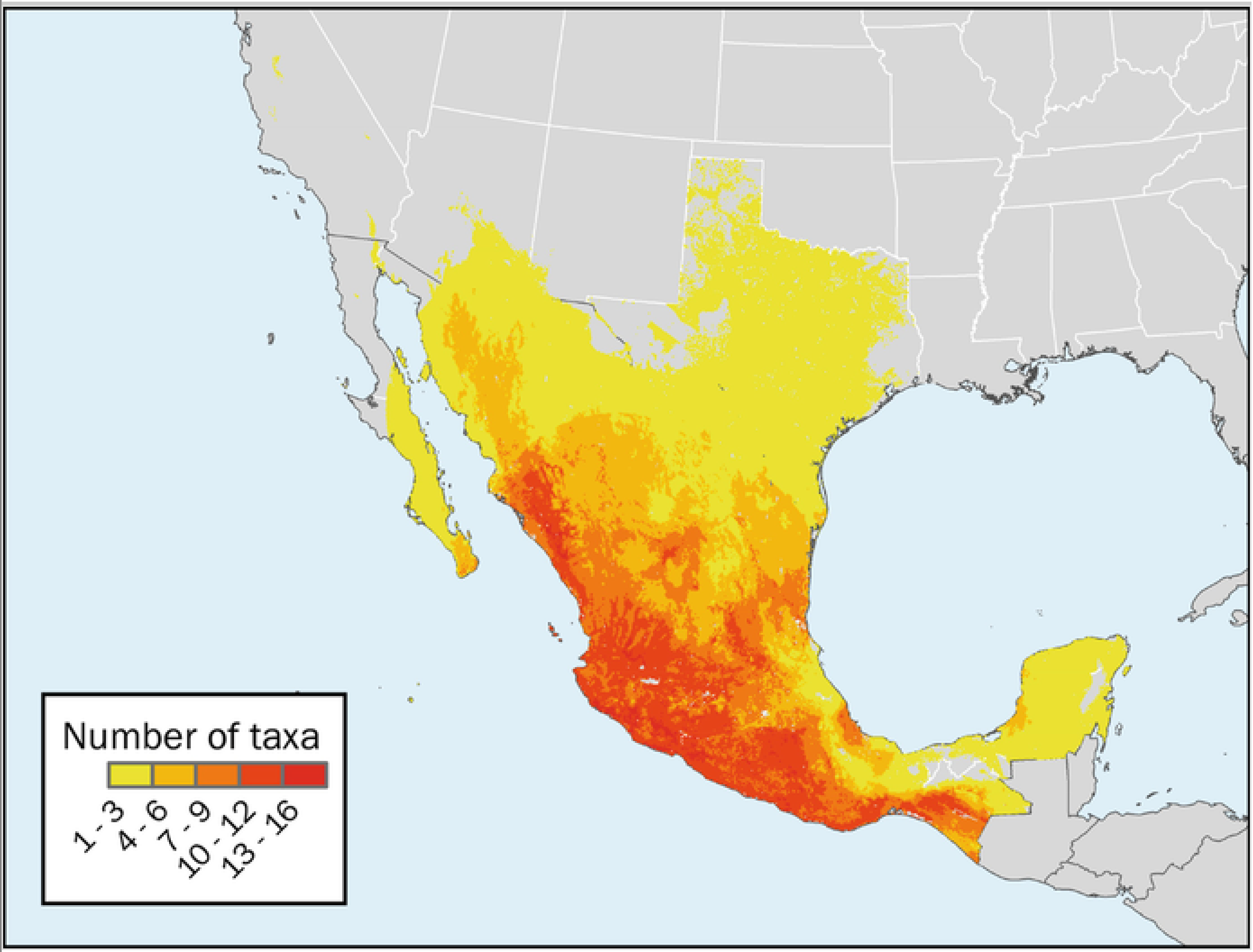
Based on occurrence points relative to distribution maps and published literature

8.8.2. Crop Wild Relatives and Wild Use

The closest wild relatives are *M. flabellifolia* Pohl and *M. peruviana* Müll. Arg, but many members of the secondary genepool are also believed to spontaneously cross with cultivated material, including *M. irwinii* D. J. Rogers & Appan, *M. pruinosa* Pohl, *M. triphylla* Pohl, and *M. tristis* Müll. Arg (Allem et al. 2001). The wild relatives are distributed across southern North America (Fig. 8.5).

Fig. 8.5

Species richness map of modeled potential distributions of North American *Manihot* taxa, based on climatic and edaphic similarities with herbarium and genebank reference localities. Warmer colors indicate areas where greater numbers of taxa potentially occur in the same geographic localities. Full methods for generation of maps and data providers are given in Appendix 1



8.8.3. Conservation Status

The largest collection of cassava is housed at International Center for Tropical Agriculture (CIAT) consisting of 6024 accessions (Hershey 2010). Conservation and utilization can be improved by increasing the amount of information available on specific accessions to both conservationists and breeders. The wild relatives of cassava are all in need of further conservation; they are poorly represented in germplasm banks despite their well-characterized potential in breeding. *Manihot walkerae* Croizat is listed as endangered by the US Fish and Wildlife Service (ECOS 2016), as well as globally imperiled (critically imperiled in Texas) by NatureServe (www.natureserve.org; NatureServe 2017). The rest of the species are either secure or not well explored in situ.

8.9. Beet (*Beta vulgaris* L.)

8.9.1. Introduction

Beet (*Beta vulgaris* L.), termed "nature's candy" due to its high sugar content, is an important vegetable, leaf, and forage crop. Cultivated beet was domesticated from wild sea beet (*Beta vulgaris* L. subsp. *maritima* (L.) Arcang.), with references to its uses dating back to ancient Rome and China (Panella and Lewellen 2007; Biancardi 2005). Beet breeding for high sucrose production increased rapidly when Napoleonic France needed a source of sugar after their access to sugarcane was cut off by the British blockade (McGrath et al. 2011). The cultivated beet originated in the Mediterranean, but the *Beta* genus contains species that are located all over the world. Europe currently cultivates the most beets with the highest production concentrated in France, Germany, and Russia, although there is substantial production in North America (FAO Stat 2014). Sugar beet, currently the most profitable cultigen, is a hybrid utilizing a cytoplasmic male sterility system and is generally grown as a biennial. Due to the importance of sugar, initial breeding efforts focused almost solely on this trait, which led to many early varieties having poor insect and disease resistance.

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8.9.2. Crop Wild Relatives and Wild Use

By the mid-twentieth century there were many systematic efforts to screen wild beet species from around the world for resistance to beet leafhopper, nematodes, and leaf spot disease (Panella and Lewellen 2007). Only a few beet relatives are commonly gathered in the wild and used in cuisine, and they are generally in the primary germplasm (Ghirardini et al. 2007). Only one species is native to North America (Table 8.9).

Table 8.9

Sugar beet crop wild relatives, genepool classification, and use in sugar beet breeding

Gene pool	Taxon	Native N.A. countries[a]	Breeding use	Number of accessions conserved in NPGS[b]	Number of accessions conserved in PGRC[c]	Number of accessions conserved in BGCI[d]	Number of accessions conserved in GENESYS[e]	Ex situ conservation status[f]
Tertiary	*Aphanisma blitoides* Nutt. ex Moq.	M, U	NA	NA	NA	NA	NA	Poorly conserved

[a]Canada (C), Mexico (M), USA (U), according to USDA, ARS (2017)

[b]USDA, ARS (2017)

[c]AFFC (2017)

[d]BGCI (2017)

[e]Global Crop Diversity Trust (2014) GENESYS

[f]Based on occurrence points relative to distribution maps and published literature

AQ10

8.9.3. Conservation Status

Increased conservation efforts for the North American wild beet species are needed (Table 8.9); while many wild relatives have been used, there is room to better conserve and characterize this species. *Aphanisma blitoides* Nutt. ex Moq. is ranked globally vulnerable by NatureServe (www.natureserve.org; NatureServe 2017) and would benefit from in situ conservation in protected areas as well as ex situ conservation.

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