North American Crop Wild Relatives, Volume 1

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Conservation Strategies

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This book is dedicated to the custodians of the diversity of wild plants in North America – past, present, and future

Foreword

Reinvesting in Crop Wild Relatives in North America

Nearly any place you hike a canyon, canoe a river, climb a mountain, wade a wet meadow, or weed a field in North America, you will come upon native plants that are close relatives of food, fiber, animal forage and feed, industrial oil, ornamental, and medicinal crops. On the fringes of muskegs from Hartley Bay in British Columbia to sites in northern California, you might come upon the Pacific crab apple (*Malus fusca* [Raf.] C. K. Schneid) around ancient fishing and gathering camps (Routson et al. 2012). In the watersheds of the St. Johns and Kissimmee Rivers in Florida, the vines of the rare Okeechobee gourd (*Cucurbita okeechobeensis* [Small] L. H. Bailey subsp. *okeechobeensis*) trail up into the branches of wild custard apples (*Annona glabra* L.) (Andres and Nabhan 1988; Nabhan 1989). Where I live and farm in Southern Arizona just north of the Mexican border, wild chiles (*Capsicum annuum* var. *glabriusculum* [Dunal] Heiser & Pickersgill) grow in desert canyons not far from wild grapes (*Vitis* L.), walnuts (*Juglans* L.), passion fruits (*Passiflora* L.), cassava (*Manihot* Mill), tomatillos (*Physalis* L.), and tepary beans (*Phaseolus acutifolius* A. Gray var. *acutifolius*) (Nabhan 1990; Nabhan 1991).

To many naturalists, these plants are but botanical curiosities, worthy of conservation without regard to historic or current human uses. But for crop geneticists and plant breeders, and a growing number of biodiversity conservationists, these species are especially worthy of protection, conservation, and evaluation because they may hold something of lasting value for the future of the way we live and eat on this planet.

These scientific and cultural values are exactly the reason why agricultural research and conservation management insights are not only so important but so timely. The chapters of this book represent the first comprehensive effort to assess wild crop genetic resources on our continent. Remarkably, this book arrives in our hands at just the moment in North American history when many of these plants are threatened by climate change yet also when these resources are most needed if future generations are to adapt.

The wildness in these plants confers distinct advantages not found in their domesticated cousins: tolerance to extremes of temperature and precipitation and resistance to the pests that lay waste to agricultural fields. This is why we are increasingly looking to the wild to strengthen our agriculture, particularly during this period of accelerated climate change. Farmers, orchardists, ranchers, and horticulturalists are already suffering from shifting and often heightened frequencies of drought, heat waves, catastrophic freezes, hurricanes, floods, and fires. And with the changes in these abiotic stressors come other biotic impacts to our farming systems and food security: previously unforeseen weeds, insect pests, and crop diseases that take a long-term toll on agricultural productivity and food safety.

During eras of political, economic, and environmental stress, humanity turns to consider a broader range of options than typically employed during "business as usual." This is one of those times – when agriculture is looking to draw upon a broader and deeper gene pool of crop genetic resources as a means to re-diversify and add resilience to the food plants that we depend on for survival. After decades of focusing on a relatively small genetic base of cultivated varieties for crop improvement, geneticists are now casting a much wider net, fortunately enabled by a broader portfolio of diagnostic techniques, micro-propagation practices, and biotechnologies used to select and transfer genes from wild relatives into food crops.

This is why the fact that forty-some crop wild relative species are included in the U.S. Fish and Wildlife Service's Endangered and Threatened Plant list is of great concern. To make matters worse, this list is likely to grow much larger (Rogers 2015). Analyses of North American seed plants facing extinction risks exacerbated by climate change and land use intensification (Zhang et al. 2016) would indicate that roughly 27% of the 4600 crop wild relatives documented to occur in the U.S. (Khoury et al. 2013) are likely to lose more than 80% of their habitat by the 2080s and will suffer a 50% retraction of their ranges.

As I read through the names on the current U.S. list of threatened and endangered crop wild relatives, I am struck by both their beauty and by the fragility of the plant species they represent:

- Texas wildrice (*Zizania texana* Hitchc.), an aquatic perennial with high allelic richness surviving along just a few stretches of the San Marcos River drainage of the Edwards Plateau in Texas
- The scrub plum (*Prunus geniculata* R. M. Harper) of Lake Wales Ridge in Florida, a small shrub with perfumed flowers valued by horticulturists as a showy and fragrant ornamental, closely related to the Chickasaw plum, with a fruit of probable hybrid origin that has been both culturally dispersed and cultivated for well over 150 years
- The Bakersfield prickly pear cactus [*Opuntia basilaris* Engelm. & J. M. Bigelow var. *treleasei* (J. M. Coult.) J. M. Coult. ex Toumey], with genes for drought resistance and production of compounds which protect against adult-onset diabetes, both of which desperately needed by farmers and consumers on our continent

- The puzzle sunflower (*Helianthus paradoxus* Heiser), a halophyte of the Pecos River in New Mexico and West Texas, which emerged from a chance hybrid of the common sunflower (*Helianthus annuus* L.) and the prairie sunflower (*Helianthus petiolaris* Nutt.) over 75,000 years ago, but is now far more salt tolerant than either of its parents, and most cultivated sunflower hybrids as well
- The Okeechobee gourd, a squash relative first described by John and William Bartram along the St. Johns River in Florida around the time of the Revolutionary War, which has barely survived the agricultural revolution that drained the Everglades for sugarcane production and diverted most rivers in Florida into croplands (Nabhan 1989)
- The Oahu cowpea (*Vigna o-wahuensis* Vogel), a rare perennial legume that has gone extinct on the very island in Hawaii where my daughter and grandson now live but which tenaciously hangs on for dear life in just seven small populations spread across four of the other Hawaiian Islands

I offer you these brief “personality profiles” to remind you that each of these valuable and endangered crop relatives has a distinctive character. The tasks of identifying, counting, tallying, mapping, monitoring, and managing the remaining populations of rare plant species on the verge of extinction are ever increasing. It is worth a moment of our time now and then to remember the complex ecological and human relationships surrounding each of these unique but declining plants.

It is important to remember that the contribution of wild relatives to crops is not a new phenomenon. In fact, these plants have naturally exchanged genes in traditional agricultural settings for millennia. We are all beneficiaries of such serendipitous crop diversification every time we sit down to eat a meal or drink a glass of wine or cider. They have been – and continue to be – our most useful “living library,” a set of manuals to help us maintain our food security (Gruber 2017, Khoury 2015, and in this volume).

Several of the chapters in this book point out the importance of recognizing that many crop relatives remain economic crops and cultural resources in their own right. Plant breeders do not necessarily need to “improve” some of these plants to make them acceptable to the public. For example, the fresh and dried fruits of wild chiltepín peppers (*Capsicum annuum* var. *glabriusculum*) sell for more than USD $80 per pound in much of the U.S. Southwest and northwestern Mexico. One pound of American wildrice from Minnesota streams and lakes that is hand-harvested and wood-parched by Native American foragers garners prices of up to USD $17 on Amazon. On the southern edges of the Chihuahuan Desert, consumers are willing to pay five to ten times more for a delicious semi-cultivated potato called papita güera (*Solanum cardiophyllum* Lindl) than for domesticated potatoes of exotic origin. Yet the anciently cultivated genotypes of this species are hardly if at all represented in most potato gene banks, including those in Mexico and the USA.

Wild apples (*Malus* Mill.) prized for their tartness and flavor are now included in hard ciders in the USA and Canada. Legally collected or propagated rare food crops like Price’s potato bean (*Apios priceana* B. L. Rob.), agaves (*Agave* L.), and cacti command high prices in horticultural trade. Wild prickly pears (*Opuntia* Mill.), pinyon nuts (*Pinus* L.), and ramps (*Allium tricoccum* Aiton) continue to attract almost as much attention from chefs and nutritional scientists as their cultivated counterparts do. Nevertheless, habitat fragmentation and other threats are diminishing foragers' access to these North American plants.

Beyond these direct uses, promising new applications of these plants are emerging from recent innovations in applied research. In Kansas, the Land Institute is newly domesticating perennial wild relatives of food crops, using intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkworth & D. R. Dewey) and rosinweed (*Silphium integrifolium* Michx.), a distant relative of sunflower, in their prairie-adapted polycultures (Dehaan et al. 2016; Van Tassel et al. 2017). In Missouri, botanists associated with the Missouri Botanical Garden and St. Louis University are evaluating wild relatives of commercially important fruit tree crops for development in their own right both as sources of food and as rootstocks, due to their hardiness and resistance to emerging insect pests and plagues (Allison Miller, pers. com).

In Illinois, integrated pest management teams have experimented with the native buffalo gourd (*Cucurbita foetidissima* Kunth) as a trap crop grown on the edges of squash and pumpkin fields to reduce larval damage to these crops and increase pollination efficiencies (Metcalf et al. 1980; Metcalf et al. 1982). In Arizona, our ecological research in the first in situ reserve for crop wild relatives in the USA [in Coronado National Forest] allowed us to determine how capsaicinoids and other secondary metabolites serve as "directed" chemical defenses against *Fusarium* fungi, insect pests, and seed-predating rodents in wild chiltepín peppers (Tewksbury and Nabhan 2001; Eich 2008). It may now be possible to differentially select and use the various capsaicinoids in the wild chile pepper arsenal for the discouragement of grain storage pests, prevention of fungal contamination of seeds, treatment of shingles, reduction of blood serum cholesterol and glucose, and management of attention-deficit disorders (Eich 2008; Barchenger and Bosland, this volume).

Thus, crop wild relatives are extremely valuable genetic resources, yet they also offer us their colorful and meaningful natural histories – stories of survival, if you will, of a more diverse portfolio of plants still available to humanity.

Thankfully, as many of the chapters in this book document, the conservation and use of wild relatives is getting more serious traction, with national and international initiatives looking to make a significant impact in the coming years. But these efforts are the tip of the iceberg of what is needed. As several contributions in this volume affirm, we must continue to invest in sufficiently supporting every link in the wild relative-food crop supply chain – from in situ conservation of natural habitats in national parks and biosphere reserves to ex situ seed banks, botanical gardens, and plant restoration efforts – if the entire supply and delivery system is to function for the future. It is not enough for land grant universities to invest millions in molecular biology laboratories if they end up closing down herbaria and cutting budgets of campus arboreta and experimental farms in the process. As Harvard conservation biologist E.O. Wilson once quipped, it is the "non-sexy" and more descriptive sciences of systematics, ethnobotany, biogeography, and seed storage physiology that have gotten us to where we are today.

These recently emerged opportunities will not bear fruit if our funding sources for habitat conservation and landscape management, for basic biology and seed banking, and for horticultural innovation and biomedical research focus only on the last few links of the wild relative-crop commodity supply chain. We not only need to diversify the genetic base of our food supply, we also need to diversify and sustain the many forms of conservation, restoration, and scholarly inquiry which together ensure access to these crop genetic resources.

Collectively, the chapters in this remarkable book provide a valuable overview of the best information and practices needed to safeguard and wisely use North America's crop wild relatives. Detailing the species native and naturalized in the continent and related to important food, fiber, animal forage and feed, industrial oil, ornamental, and medicinal crops, the authors outline their potential for use and highlight the conservation needs for the species. In bringing together for the first time this information from across the broad North American region, including Canada, Mexico, and the USA, the book provides access to critical conservation information for well over 600 promising plants. As this landmark volume attests, these plants are essential elements of North America's natural and cultural heritage. This book becomes the model for advancing the efforts needed to better care for this heritage for present and future generations. It provides us with operating instructions for wisely managing "our living library."

Tucson, AZ, USA Gary Paul Nabhan

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Preface

Wild plants useful to food and agriculture occupy a niche frequently outside the realm of both agricultural and natural resource professionals. The agricultural community tends to focus on a handful of domesticated species, while the natural resource community emphasizes legislatively regulated taxa (i.e., species that are rare, endangered, indicators of ecosystems such as wetlands, or wild species used for timber or revegetation).

The increasing challenges to food and agricultural production due to climate change, added to the ever-present biotic and abiotic stresses, are likely to make crop wild relatives and other useful wild plants more of a priority to both communities. And the combined efforts of both communities will be critical to locating, conserving, and making available these invaluable species to support agricultural production and food and nutritional security for future generations.

The purpose of this two-volume book is to highlight the most important wild plant genetic resources that grow in North America. We define these resources as wild species with relevance for agriculture. These include the wild plant populations from which domesticated varieties evolved, crop wild relatives that can be used to improve contemporary crops, wild species that have a record of use by people, and any other wild species with potential for future crop development. Most of the species covered are native, but a few are introduced taxa that have become naturalized in the region. A thorough understanding of the species that occupy North America, including their distributions, potential value to agriculture, and conservation statuses and needs, will give agricultural and conservation communities the basic knowledge they need to take steps to conserve our natural heritage of useful wild plants.

The overarching goal of this book is to help ensure that these valuable but overlooked species continue to persist, both in their natural habitats and in gene banks, where they can be made available as resources to address compounding agricultural and nutritional challenges. This book is authored by a broad range of experts working diligently to explore, protect, celebrate, and use crop genetic resources. They have come together to compile the latest information on the most important North American wild useful plants. This book focuses on Canada, the USA, and Mexico, three countries whose combined area covers most of the continent.

The first volume of the book covers topics relevant to the conservation of all wild plant genetic resources, while the second volume focuses on specific crops and their related wild taxa. Volume One: Conservation Strategies begins by reviewing efforts, challenges, and opportunities to conserve food and agriculturally important wild species from a national perspective. The first part provides not only a broad overview of important crop wild relatives and wild utilized species in Canada, Mexico, and the USA but also a description of the agencies and institutes focused on conserving these plants, as well as the conservation and use policies followed by each country. This section concludes with a chapter that presents Native American tribal perspectives in the USA, providing a glimpse into the management and regulation of plant genetic resources by Indigenous peoples through a set of case studies of several tribal governments.

The second part of Volume One discusses various aspects of wild plant genetic resource conservation methodologies. Managing genetic resources of wild plants involves additional considerations beyond those required for domesticated crops. Likewise, wild genetic resource conservation differs from managing plant species that are rare and endangered in that a greater emphasis is placed on ex situ activities, including storage and seed regeneration, that ensure that these resources are available for use by plant breeders and the scientific community. This section is organized in a logical sequence that begins with a chapter on current and emerging frameworks on defining wild genetic resources, as well as a chapter on threat assessments. Two subsequent chapters cover sampling strategies and collecting practicalities, followed by chapters that discuss aspects of gene banking wild species, including storage and seed increase. Volume One concludes with a chapter that discusses public education and outreach opportunities for crop wild relatives.

There are over 20,000 plant species in North America, and all deserve a chance to thrive. However, a small fraction of these are distinguished by their potential to support food and agricultural production, either because they are resources that can be used to breed more productive crops or because they have commercial or cultural value when used directly. Many of these species are common, even weedy, and are easily overshadowed by rare or endangered plants. Nevertheless, because of their real or potential importance to our food and agriculture, they deserve to be recognized, celebrated, conserved, and made available for use.

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Abbreviations

AAFC	Department of Agriculture and Agri-Food Canada
ABS	Access and Benefit Sharing
ABSA	Access and Benefit Sharing Agreement
AFLP	Amplified fragment length polymorphism
AHLV	American hop latent virus
AHPA	American Herbal Products Association
AMJB	Mexican Association of Botanical Gardens
ANSI	American National Standards Institute
ANSM	Universidad Autónoma Agraria Antonio Narro
AOSCA	Association of Official Seed Certifying Agencies
APGA	American Public Gardens Association
ApMV	Apple mosaic virus
ARS	Agricultural Research Service
ASU	Arizona State University
ATBI	All Taxa Biodiversity Inventory
AZ	Arizona
BCMV	Bean common mosaic virus
BGCI	Botanic Gardens Conservation International
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BONAP	Biota of North America Program
BP	Before present
BP&P	Bayesian phylogenetics and phylogeography
Bt	Bacillus thuringiensis
BTA	Boyce Thompson Arboretum
CA	California
CAM	Crassulacean acid metabolism
CAPS	Cleaved amplified polymorphic sequences
CBCN	Canadian Botanical Conservation Network
CBD	Convention on Biological Diversity
CBIF	Canadian Biodiversity Information Facility

CCC	Civilian Conservation Corps
CCD	Colony collapse disorder
CCGB	Canadian Clonal Genebank
CCN	Conservation Center Network
CDFW	California Department of Fish and Wildlife
CDI	National Commission for the Development of Indigenous Peoples
CEVAMEX	Valle de México Research Station
CFIA	Canadian Food Inspection Agency
CGC	Crop Germplasm Committee
CGN	Centre for Genetic Resources
CIAT	International Center for Tropical Agriculture
CICTAMEX	Scientific and Technological Research Center of Avocado in the State of Mexico
CICY	Yucatan Center for Scientific Research
CIMMYT	International Maize and Wheat Improvement Center
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLCuD	Cotton leaf curl disease
CMS	Cytoplasmic male sterility
CMV	Cucumber mosaic virus
CNHP	Colorado Natural Heritage Program
CNRG	National Genetic Resources Center
Co	County
CONABIO	National Commission for the Knowledge and Use of Biodiversity
CONANP	National Commission of Natural Protected Areas
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CP	Coefficient of Parentage
CP	Postgraduate College
CPB	Cartagena Protocol on Biosafety
CPC	Center for Plant Conservation
CPGR	Canadian Potato Genetic Resources
CPNWH	Consortium of Pacific Northwest Herbaria
CS	College Station Texas
CSIRO	Commonwealth Scientific and Industrial Research Organization
CSN	Counter Season Nursery
CWR	Crop wild relatives
DELEP	Desert Legume Program
DMI	Dobzhansky-Muller incompatibilities
DNA	Deoxyribonucleic acid
DNR	Department of Natural Resources
DOD	Department of Defense
DOE	Department of Energy
DOF	Official Gazette of the Federation
DOT	Department of Transportation

EC	Electrical conductivity
ECOS	Environmental Conservation Online System
ELISA	Enzyme-linked immunosorbent assay
EMCV	Mexican Plant Conservation Strategy
ENBioMex	National Biodiversity Strategy of Mexico
ENGOs	Environmental non-governmental organizations
ENM	Ecological niche model
ESA	Endangered Species Act
EUFGIS	European Information System on Forest Genetic Resources
FAO	Food and Agriculture Organization of the United Nations
FES-I	Faculty of Higher Education Iztacala
FGP	Frost grape polysaccharide
FNA	Flora of North America
FRRL	Forage and Range Research Laboratory
G	Global
GBIF	Global Biodiversity Information Facility
GBS	Genotyping by sequencing
GG	Germplasm Resource Information Network-Global database
GH	Greenhouse
GIS	Geographical Information Systems
GLIFWC	Great Lakes Indian Fish and Wildlife Commission
GLS	Gray leaf spot
GMP	Good Manufacturing Practice
GP	Genepool
GPS	Global Positioning System
GRIN	Germplasm Resource Information Network database
GS	Genome selection
GWAS	Genome-wide association study
Ha	Hectare
HPLC	High-performance liquid chromatography
HpLV	Hop latent virus
HpMV	Hop mosaic virus
HPTLC	High-performance thin-layer chromatography
HRT	Hormone replacement therapy
ICAMEX	Institute for Training, Research, and Development in Agriculture of the State of Mexico
ICAR	Indian Council on Agricultural Research
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
iDIGBio	Integrated Digitized Biocollections
IGRR	In Situ Genetic Resource Reserve
IICA	Inter-American Institute for Cooperation on Agriculture
ILDB	The International Lactuca Database
INDR	Indiana Department of Natural Resources
INIFAP	National Institute of Forestry, Agriculture and Livestock Research
INRA	French National Institute for Agricultural Research

INTA	Instituto Nacional de Tecnología Agropecuaria
IPGRI	International Plant Genetic Resources Institute
IPK	Leibniz-Institut für Pflanzengenetik und Kulturpflanzenforschung
IPR	Intellectual property rights
ISO	International Standards Organization
ISSR	Inter-simple sequence repeat
ITIS	Integrated Taxonomic Information System
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
IUCN	International Union for Conservation of Nature
KBIC	Keweenaw Bay Indian Community
LBOGM	Law on Biosafety of Genetically Modified Organisms
LFVV	Federal Law on Plant Varieties
LGCC	Law on Climate Change
LGCS	USDA Lactuca Germplasm Collection in Salinas
LGRCD	Lactuca Genetic Resources Collection at the University of California in Davis
MCMV	Maize chlorotic mosaic virus
Mha	Million hectares
MLN	Maize lethal necrosis
MLS	Multilateral system
MRC	Major resistance clusters
MRCA	Most recent common ancestor
MS	Flow injection mass spectrometry
MSB	Millennium Seed Bank
MSBP	Millennium Seed Bank Project
MT	Metric tons
MTA	Material Transfer Agreement
N	National
n/d	Not determined
NA	North America
NALPGRU	National Arid Land Plant Genetic Resources Unit
NARO	National Agriculture and Food Research Organization
NASS	National Agricultural Statistics Service
NBSAP	National Biodiversity Strategy and Action Plan
Nc	Census population size
NCGC	National Cotton Germplasm Collection
NCGR	National Clonal Germplasm Repository
NCGR-Davis	National Clonal Germplasm Repository in Davis, California
NCRPIS	North Central Regional Plant Introduction Station
Ne	Effective population size
NGRL	National Germplasm Resources Laboratory
NGS	Next-generation sequencing
NILs	Near isogenic lines
NKLP	Nagoya–Kuala Lumpur Protocol on Liability and Redress

NLGRP	National Laboratory for Genetic Resources Preservation
NLR	Nucleotide binding-leucine rich repeat receptor
NM	New Mexico
NMFS	National Marine Fisheries Service
NMR	Nuclear magnetic resonance
NOM-059	NOM-059-SEMARNAT-2010-Mexican standard that lists all threatened native wild species
NORGEN	North American Regional Network for Agricultural Research-Genetic Resources Task Force
NP	Nagoya Protocol
NPA	Natural Protected Areas
NPABS	Nagoya Protocol on Access and Benefit Sharing
NPGS	USDA, ARS National Plant Germplasm System
NPS	National Park Service
NRCS	USDA, Natural Resources Conservation Service
NS SEME	Novi Sad Institute of Field and Vegetable Crops
NS/S	Native Seeds/Search
NSL	United States Forest Service National Seed Laboratory
NUS	Neglected underutilized species
OPGC	Ornamental Plant Germplasm Center
OR	Oregon
OSU	Ohio State University
PacBio	Pacific Biosystems
PANREFI	National Plan of Action for the Conservation of Plant Genetic Resources for Food and Agriculture
PBLS	Pecan bacterial leaf scorch
PCA	Plant Conservation Alliance
PCB	Cartagena Protocol on Biosafety
PCN	Plant Conservation Network
PCR	Polymerase chain reaction
PEO	USDA, ARS Plant Exchange Office
PGRC	Plant Gene Resources of Canada
PGRFA	Plant Genetic Resources for Food and Agriculture
PI	Plant Introduction
PMC	USDA, Natural Resources Conservation Service Plant Material Center
PROCINORTE	North American Regional Network for Agricultural Research
PRV	Papaya ringspot virus
PVG	Pre-variety germplasm
PVP	US Plant Variety Protection
QTL	Quantitative trait loci
RAPD	Random amplified polymorphic DNA
RBG Kew	Royal Botanical Gardens Kew
RGC16	Family of nucleotide binding-leucine rich repeat receptor (NLR) proteins

RGC2	Resistance Gene Candidate 2
RMA	Research Marketing Act
RNA	Research Natural Area
RNA	Ribonucleic acid
S	Subnational
SAGARPA	Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food
SBBG	Santa Barbara Botanic Garden
SCP	Species Conservation Plan
SDBG	San Diego Botanic Garden
SDG	Sustainable Development Goals
SDM	Species distribution model
SEINet	Southwestern Environmental Information Network
SEMARNAT	Ministry of the Environment and Natural Resources
SID	Seed Information Database
SINAREFI	National Program of Plant Genetic Resources for Food and Agriculture
SMTA	Standard material transfer agreement
SNICS	National Seed Inspection and Certification Service
SNP	Single nucleotide polymorphisms
SNWA	Southern Nevada Water Authority
SOMEFI	Mexican Society of Plant Genetics
SOP	Standard operating procedure
SOS	Seeds of Success
SS	Sequence-tagged site
SSR	Simple sequence repeat
SW	Southwestern
SWD	Spotted wing drosophila
TES	Threatened, Endangered, and Sensitive Species
TEX	University of Texas
Tg	Glass transition temperature
TNC	The Nature Conservancy
TNPD	Texas Native Plants Database
TRAP	Target region amplification polymorphism
TRIPS	Trade-Related Aspects of Intellectual Property Rights
TVA	Tennessee Valley Authority
TX	Texas
UAAAN	Antonio Narro Agrarian Autonomous University
UACh	Chapingo Autonomous University
UBC-BG	University of British Columbia Botanical Garden
UC Davis V&E	The University of California, Davis Viticulture and Enology Department
UCBG	University of California Botanical Garden
UDG	University of Guadalajara
UGto	University of Guanajuato

UMA	Wildlife Conservation Management Units
UNAM	National Autonomous University of Mexico
UNCCD	United Nations Convention to Combat Desertification
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFAO	United Nations Food and Agriculture Organization
UNFCCC	United Nations Framework Convention on Climate Change
UPOV	International Union for the Protection of New Varieties of Plants
UPP	Useful Plants Project
URL	Uniform Resource Locator
US	United States
USA	United States of America
USD	United States Dollars
USDA	United States Department of Agriculture
USDA-ARS	United States Department of Agriculture – Agricultural Research Service
USDOI	United States Department of the Interior
USFS	United States Forest Service
USFWS	US Fish and Wildlife Service
USFWS	United States Fish and Wildlife Service
UT	Utah
UV	University of Veracruz
VASCAN	Database of Vascular Plants of Canada
VIR	Vavilov All-Russian Research Institute of Plant Industry
VNIIMK	All Russian Research Institute of Oil Crops
WGD	Whole genome duplication
WMV	Watermelon mosaic virus
WRPIS	USDA, ARS Western Regional Plant Introduction Station
WTO	World Trade Organization
WUS	Wild utilized species
WY	Wyoming
YUNGA	Youth and United Nations Global Alliance
ZWMV	Zucchini yellow mosaic virus