

Safeguarding and Distributing Priority Native Crop Wild Relative Genetic Resources of the United States

USDA National Genetic Resources Advisory Council

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Cucurbita palmata S. Watson, photo by Heather Rose Kates. For more information on the wild relatives of pumpkins, see Khoury et al. 2019 <https://doi.org/10.1002/ppp3.10085>

Executive Summary

Crop wild relatives and other wild utilized plants of the United States represent important parts of our regional natural and cultural resources. Many of the plants have been significant sources of food, spice, medicine, or other uses for people for centuries with significant economic impact. Through plant breeding and other research, they are critical in contributing to productivity, diversification, and greater resilience in agricultural systems. But as wild plants, they are threatened by habitat loss, climate change, and many associated impacts. The window of opportunity to secure them in conservation systems will not be open indefinitely and hence we need to act now. The cost of failure to act will result in lack of access and disappearance of American crop wild relatives.

Key messages about crop wild relatives and their importance include:

- Crop wild relatives - the wild cousins of agricultural plants - are valuable genetic resources used by plant breeders to increase yield, pest and disease resistance, and many other traits critical to the productivity, quality, and sustainability of agricultural crops.
- The United States harbors a rich native flora of wild relatives of important food crops – wild apples, beans, blueberries, chile peppers, corn, grapes, hops, onions, pumpkins, sunflowers, and many more – as well as wild cousins of economically important fiber, industrial, feed and forage, medicinal, and ornamental crops.
- Our resident crop wild relatives are not yet comprehensively safeguarded in the USDA-ARS National Plant Germplasm System (NPGS), and many species’ natural habitats are threatened. Conserving plants in their natural habitats is important as it is more dynamic and allows for the plants to continue evolving in their natural environments. These conservation gaps limit the portfolio of genetic resources available to present and future generations.
- Key actions that will support the long-term conservation of our native crop wild relatives that are within the capacity of USDA include:
 - 1) Collecting and conserving native crop wild relative germplasm of high potential value in the NPGS will enable the long-term protection and availability of these natural resources.
 - 2) Establishment of conservation management plans for those species inhabiting USFS lands will strengthen their potential to persist and continue to evolve in their natural habitats.
 - 3) Intensive collaborations between Agencies under OneUSDA, as well as strategic partnerships with other key research, conservation, and land management organizations, will enable the comprehensive effort required to fully safeguard and make these resources accessible into the future.

Strengthening Food Security and Rural Agricultural Economies by Conserving and Using Crop Wild Relatives

Growing populations and changing dietary expectations across the world are increasing the demand for more and better food at a rate that brings into question how staple crop yield gains will keep pace. Meanwhile, our nation's producers are facing natural resource input limitations and changing weather patterns, while trying to respond to calls to improve soil and water conservation, reduce greenhouse gas emissions, and better protect the pollinators and other ecosystem services that bolster crop production. In short, the challenge of feeding the world sustainably in the coming decades is formidable.

A key pathway to producing more and better food with less environmental impact is through improved varieties of crops, bred to be productive, nutritious, and efficient even under stress. To develop these new varieties, plant breeders utilize diverse genetic resources as well as the information contained within them. Public and private breeders alike look to the USDA-ARS National Plant Germplasm System (NPGS) as a key source of this crop genetic diversity. The world's largest national public genebank, the NPGS maintains close to 596,000 accessions of over 13,000 crops and other useful plants. Via the online information and ordering system "GRIN-Global", the NPGS makes this wealth of genetic resources and associated data available for plant breeding, research, and education. The collections held in the NPGS should continue to expand as necessary to serve the needs of these users as they evolve.

The Crop Vulnerability Updates (CVU) developed by almost every Crop Germplasm Committee (CGC) associated with the NPGS list crop wild relatives (CWR) as a priority. Priority issues identified include conducting gap analyses for the collections, acquisition of additional samples of CWR, strengthening collaborations to protect threatened CWR *in situ* (in their natural habitats) and ensuring the conservation of CWR diversity both *in situ* and *ex situ* (outside their natural habitats, for example in a genebank).

A trans-disciplinary group of researchers, conservation practitioners, and public outreach professionals recently identified five essential activities through which land managers, agricultural research organizations, botanic gardens, and other conservation, crop development, and public outreach/education organizations need to collaborate to significantly strengthen native crop wild relative conservation in the region. Building on that group's recommendations, this document was drafted by members of the National Genetic Resources Advisory Council (NGRAC) after extensive discussion.

Background

As sources of genetic diversity, crop wild relatives - the wild progenitors and cousins of agricultural crop species - are widely viewed as having proven value, contributing a wide range of beneficial agronomic and nutritional traits to crops over recent decades. These wild plants are often more resilient than their domesticated kin to extreme climates and difficult soils, and to challenging pests and diseases (*Figure 1*). Due to the close genetic relationship of these plants with their cultivated cousins, useful traits can be introgressed from wild relatives into crops with relative ease and without costly regulation expense. Their utilization as genetic resources is expected only to increase in the future as a consequence of ongoing improvements in information on the plants and their diversity, and continuing advances in breeding methods and tools.

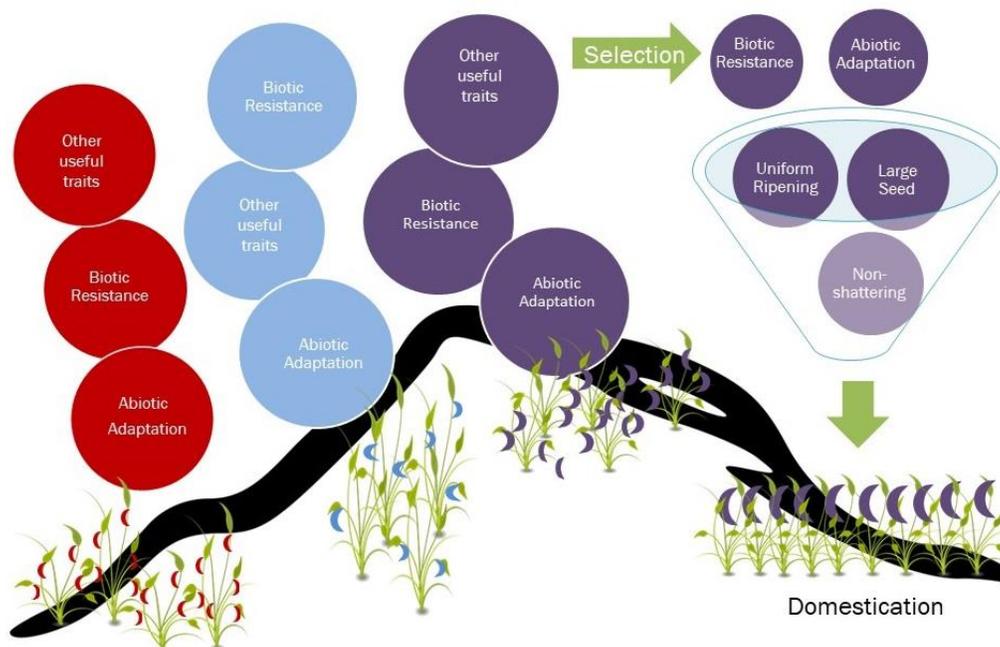


Figure 1. Adaptation to different environments, for example, along an elevation gradient in mountainous terrain, results in unique wild ecotypes of a species (colors represent different ecotypes, each with a unique suite of traits that contribute to its survival) Although the domestication process results in crops more suitable for human use, a general tradeoff is the reduction in genetic diversity, (represented by the size and uniform color of bubbles after selection for traits such as uniform ripening, large seededness, and non-shattering, important traits for successful cultivation of crops). Left behind in the wild are the many adaptive traits from ecotypes, that may be, potentially valuable to develop crops resilient to the challenges of a changing production environment. Figure from Greene et al. (2018).

However, these high hopes for crop wild relatives are based on the assumption that their genetic resources will be readily available for use, which requires their conservation as germplasm accessions in genebanks such as the NPGS, as well as functioning mechanisms to enable access to this diversity. To support the long-term potential of these wild plant genetic resources, protecting diverse populations in their natural habitats, where they can continue to evolve alongside pests, diseases, heat, drought, and other stresses, is also necessary.

The NPGS has served as a major provider of crop wild relatives to plant breeders over previous decades. This said, the NPGS crop wild relative collections, along with those of other publicly accessible genebanks, have recognized gaps. At the same time, the habitats of a wide range of wild relatives are threatened by urbanization, agricultural expansion, invasive species, mining, climate change, pollution, over-harvesting, and more. Even in protected natural areas, such plants are often vulnerable due to inadequate prioritization and insufficient resources to manage the populations.

Since 2011, an ambitious 10-year, \$50 million international project has been funded by the Government of Norway and implemented by the Global Crop Diversity Trust and partners, with the aims of resolving genebank collection gaps for the wild relatives of crops important for food security worldwide and “pre-breeding” with these relatives to produce materials of interest to plant breeders. The U.S. was recognized during the project as an important hotspot for crop wild relatives, with many important native species inadequately represented in public genebanks. Although USDA, academic, and other U.S. research organizations have partnered with the global initiative in a variety of significant ways, the core work of collecting, conserving, and making available native crop wild relatives has been left to the nation to accomplish.

A concerted national effort devoted to improving the conservation and availability of our native wild relatives for crop improvement is thus timely for prominent objectives ranging from achieving food security and improving rural agricultural livelihoods to sustainably managing natural resources and conserving biodiversity. These goals embody the customer-focused vision of the USDA, whose national genebank is not only the world’s largest, but also the largest distributor of germplasm to global customers. As the manager of the greatest number of protected natural areas in the nation, USDA is uniquely positioned to play a pivotal role in this effort. Success requires intensive collaborations across Agencies as envisioned under OneUSDA, as well as partnerships with other key research, conservation, and land management organizations. The window of opportunity to resolve the deficiencies for these useful plants will not remain open indefinitely. The time to act is now.

Economic Impact of Crop Wild Relatives of the United States

Native crop wild relatives have proved extremely useful in breeding more productive and efficient cultivated plants. Examples of uses of American crop wild relatives include:

- Wild grapestocks that proved critical for resistance to the devastating insect phylloxera in European grape production in the late 1800’s. These grapestocks continue to provide the basis for protection worldwide. More recently, native wild relatives have contributed important pest and disease resistance genes including for powdery mildew, to grapes.
- Genes for hybrid breeding, pest and disease resistance, salt tolerance, and pesticide resistance have been successfully introgressed from wild sunflowers into cultivars.

- The globally important hop cultivar “Brewer’s Gold” was derived from an American wild parent species.
- A native apple species has improved resistance to fire blight in the domesticated fruit.
- Wild blueberry relatives have played a significant role in the improvement of the cultivated species in the U.S., most famously with wild plants from New Jersey selected to become what is known as the northern highbush blueberry crop. Later crosses between northern highbush and other wild relatives led to low chilling, heat- and drought-tolerant southern highbush cultivars adapted to the southeastern U.S.

The economic return on investment in crop wild relatives is enormous. In the 1990s, crop wild relatives were estimated to contribute **\$20 billion** toward increased crop yields annually in the U.S. and \$115 billion worldwide, with traits of potential use found in threatened and endangered wild relatives valued at \$10 billion annually. A 2013 report conducted by PricewaterhouseCoopers (PwC) that was commissioned by Kew’s Millennium Seed Bank in the UK estimated the global value of genes from the wild relatives of 30 important food crops to be **\$120 billion** per year. The annual economic contribution of sunflower wild relatives, which are almost entirely native to the U.S., was recently estimated at **\$267-384 million**.

An inventory of U.S. crop wild relatives conducted by Khoury et al. in 2013 recognized almost 2,000 species of current or potential value to food, fiber, industrial, feed and forage, medicinal, and ornamental crops. Of these, around 300 native species were prioritized as potentially highly useful relatives of important food crops. These include the wild cousins of crops that were domesticated in pre-Columbian times by Native Americans, such as sunflower and squash, as well as more recent domesticates, such as blueberry, cranberry, raspberry, blackberry, and pecan. These are our nation’s native food crops, with the responsibility for caretaking their progenitors and wild cousins resting solely on our shoulders.

Other priority species include the northernmost-occurring wild relatives of Mesoamerican crops such as corn, bean, chili pepper, and cotton, as well as useful cousins of temperate crops first domesticated in Europe and Asia, such as onion, grape, apple, strawberry, hops, and walnut. In combination, our resident crop wild relatives can be found in just about every corner of the nation, with particular abundance of species in the Northeast to the Midwest, the Eastern Seaboard and Gulf Coast, the Pacific coast, and the mountains of the Southwest (*Figure 2*).

If properly collected, conserved, and made accessible to breeders and other researchers, these crop wild relatives will constitute an extremely diverse portfolio supporting present and future crop improvement efforts.

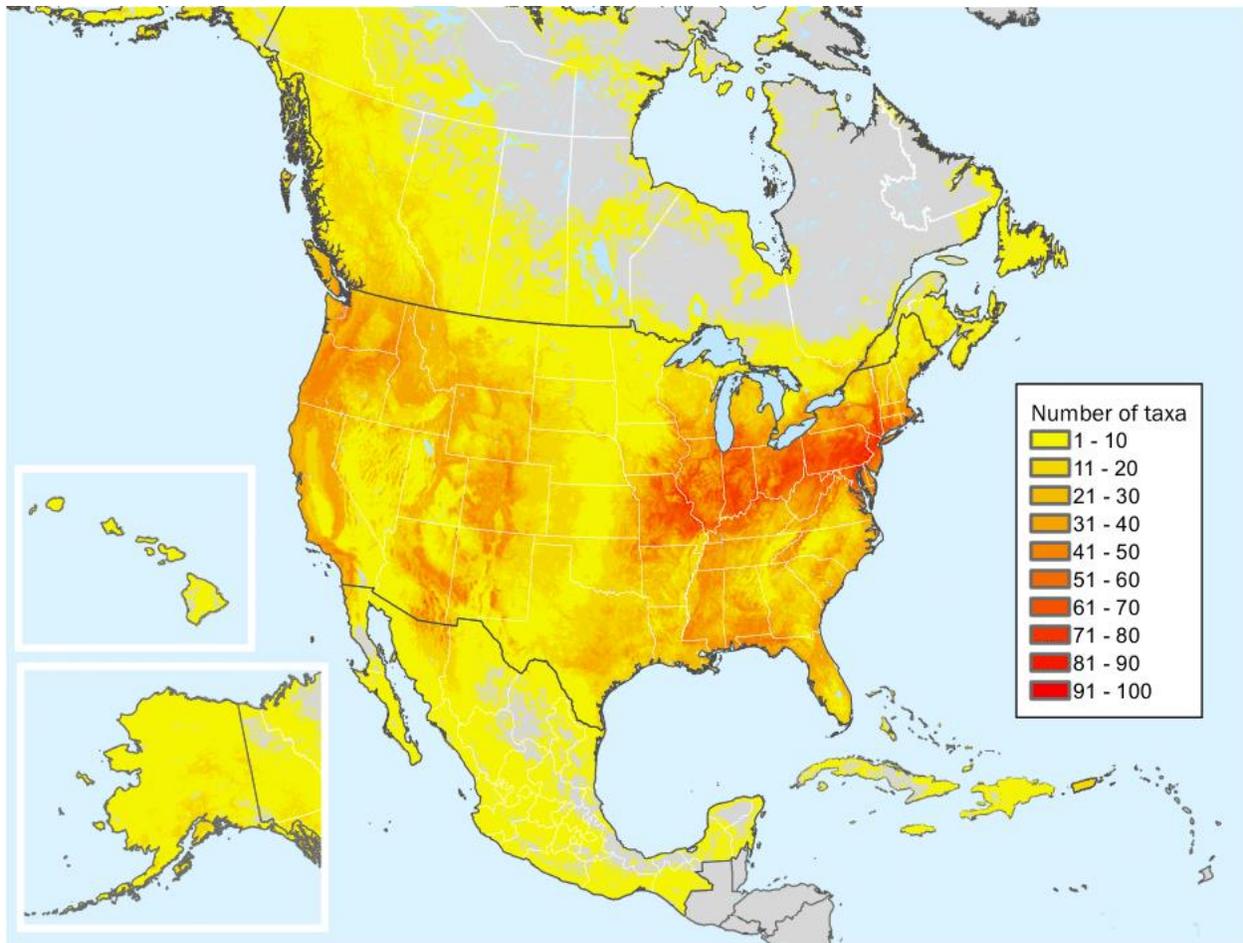


Figure 2. Richness map combining the potential ranges of 550 crop wild relatives in the U.S. Warmer colors indicate where greater numbers of taxa potentially occur in the same geographic area. Figure from Khoury et al. 2020

Threats to American Crop Wild Relatives

A recent national-level assessment of the state of representation of important crop wild relatives in the NPGS and other *ex situ* conservation programs indicates that considerable further conservation work is needed (Khoury et al. 2020). Some 80% of the 594 assessed taxa were assessed high priority for further collecting for *ex situ* conservation, with 82 wild relatives (13.8%) currently absent from conservation repositories, and an additional 197 (33.2%) represented by fewer than 10 accessions, thus offering limited genetic variation available for crop breeding and other research. Areas of the country with the greatest numbers of under-represented species include Northeast and Midwest, the Pacific Northwest and California, the Mountain West and Southwest, and the Gulf Coast region of the Southeast, although collecting targets were identified in all 50 states as well as Washington D.C. and U.S. territories. Many of the ranges of these species overlap with areas of high human population density. Disparately, most of the protected areas (Figure 3) are not necessarily in the more species dense regions.

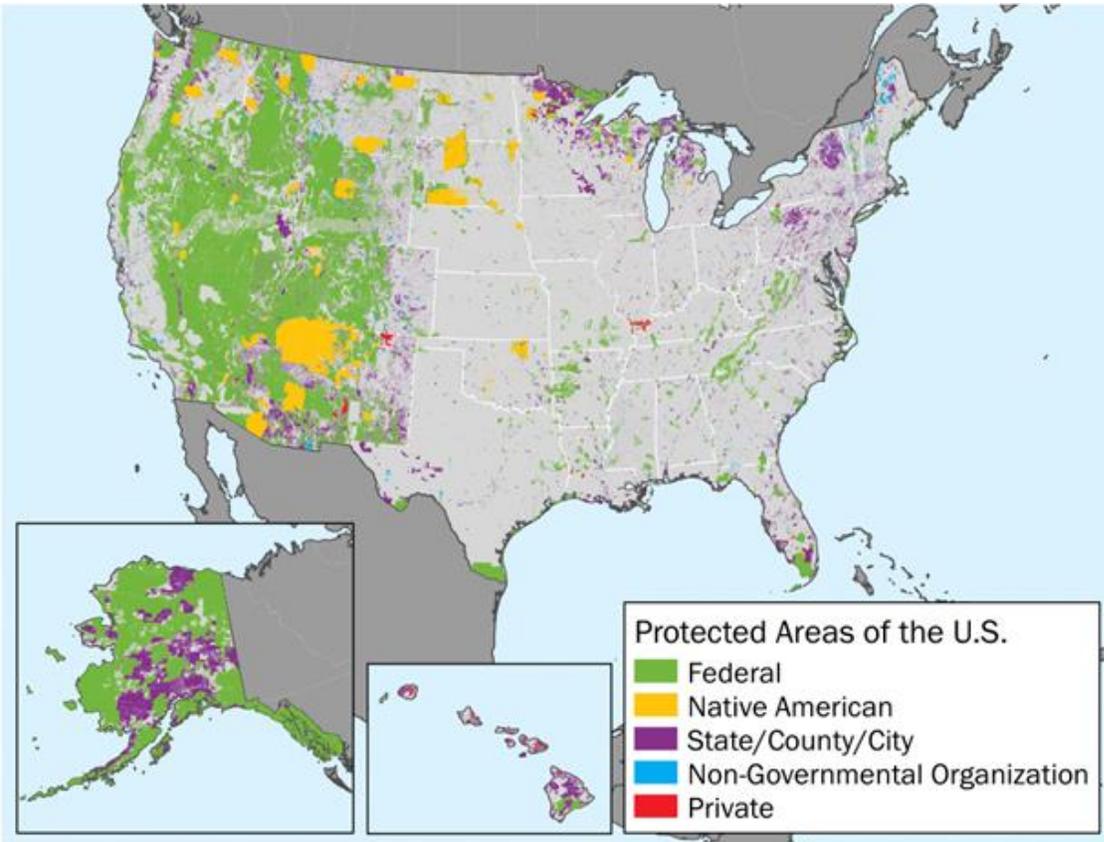


Figure 3. Protected areas in the United States. Based on data downloaded from the Protected Areas Database (PAD-US). Figure from Williams and Greene (2018)

Recent analyses have also emphasized the lack of data on the useful traits hidden within such species as a significant hindrance to use. These and other persisting challenges to the conservation, management, and availability for use of crop wild relatives limit the portfolio of genetic resources and information available to present and future generations of agricultural researchers, and thus ultimately to the producers and consumers who benefit from their work.

The urgency of resolving conservation gaps for wild relatives is heightened by threats to their natural populations from habitat loss, pollution, invasive species, climate change, over-harvesting and more³⁷⁻⁴². Dozens of native crop wild relatives are listed under the U.S. Endangered Species Act or in the threatened species lists produced by NatureServe, a non-profit organizational source of threat status information (*Table 1*). Examples include northern California walnut, which is a primary rootstock for English walnut and is critically imperiled in its native habitat, and Pecos sunflower, an important source of salt tolerance for the cultivated sunflower (*Figure 4*). Other vulnerable species include close relatives of cotton, currants, onions, plums, raspberries, and pumpkins. The same recently completed national level conservation analysis covering almost 600 important native wild relatives determined 11.3% of taxa as high priority, and 81.8% medium priority for increased habitat protection (Khoury et al. 2020).

Table 1: Threatened U.S. wild relatives of major crops

Species	Associated crop	Endangered Species Act listing	NatureServe threat level	Number of accessions in NPGS
<i>Allium munzii</i> (Ownbey & Aase ex Traub) McNeal	Onion	LE	G1	4
<i>Allium obtusum</i> Lemmon var. <i>conspicuum</i> Mortola & McNeal	Onion		T2-3	0
<i>Allium scilloides</i> Douglas ex S. Wats.	Onion		G2-3	0
<i>Cucurbita okeechobeensis</i> (Small) L. H. Bailey	Pumpkin	LE	G1	1 (+ 43 of subspecies)
<i>Fragaria chiloensis</i> (L.) Mill. subsp. <i>sandwicensis</i> (Decne.) Staudt	Strawberry		T2	2
<i>Gossypium tomentosum</i> Nutt. ex Seem.	Cotton		G2	41
<i>Helianthus carnosus</i> Small	Sunflower		G1-2	6
<i>Helianthus niveus</i> (Benth.) Brandegee subsp. <i>tephrodes</i> (A. Gray) Heiser	Sunflower		T2	15
<i>Helianthus nuttallii</i> Torr. & A. Gray subsp. <i>parishii</i> (A. Gray) Heiser	Sunflower		TH	0
<i>Helianthus paradoxus</i> Heiser	Sunflower	LT	G2	22
<i>Helianthus smithii</i> Heiser	Sunflower		G2	10
<i>Helianthus verticillatus</i> Small	Sunflower	LE	G1	2
<i>Hordeum arizonicum</i> Covas	Barley		G2-4	1
<i>Ipomoea microdactyla</i> Griseb.	Sweetpotato		G2	2
<i>Juglans hindsii</i> (Jeps.) R. E. Sm.	Walnut		G1	19
<i>Lathyrus grimesii</i> Barneby	Grasspea		G2	3
<i>Lathyrus holochlorus</i> (Piper) C. L. Hitchc.	Grasspea		G2	1
<i>Leymus pacificus</i> (Gould) D. R. Dewey	Rye and Wheat		G2-3	0
<i>Manihot walkerae</i> Croizat	Cassava	LE	G2	1
<i>Phaseolus texensis</i> A. Delgado & W. R. Carr	Bean		G2	0
<i>Prunus eremophila</i> Prigge	Almond, cherry, plum, etc.		G1	0
<i>Prunus geniculata</i> R. M. Harper	Almond, cherry, plum, etc.	LE	G3	3
<i>Prunus murrayana</i> E. J. Palmer	Almond, cherry, plum, etc.		GH	0
<i>Ribes binominatum</i> A. Heller	Currant		G2-3	3
<i>Ribes echinellum</i> (Coville) Rehder	Currant	LT	G1	3
<i>Ribes erythrocarpum</i> Coville & Leiberger	Currant		G2	18
<i>Rubus aliciae</i> L. H. Bailey	Raspberry, blackberry		GH	0
<i>Rubus hawaiiensis</i> A. Gray	Raspberry, blackberry		G2-3	14
<i>Rubus macraei</i> A. Gray	Raspberry, blackberry		G2	0
<i>Solanum incompletum</i> Dunal	Potato	LE	G1	0
<i>Solanum nelsonii</i> Dunal	Potato	PE	G2	0
<i>Solanum sandwicense</i> Hook. & Arn.	Potato	LE	G1	0
<i>Solanum wallacei</i> (A. Gray) Parish	Potato		G2	0
<i>Tripsacum floridanum</i> Porter ex Vasey	Corn		G2	1
<i>Vanilla Mexicana</i> Mill.	Vanilla		G2-4	0
<i>Vicia menziesii</i> Spreng.	Vetch	LE	G1	0
<i>Vicia ocalensis</i> R. K. Godfrey & Kral	Vetch		G1	1
<i>Zizania texana</i> Hitchc.	Wildrice	LE	G1	0

Species listed as endangered (LE), threatened (LT), or proposed endangered (PE) under the United States Endangered Species Act, and/or listed as known or presumed extinct in the wild (GH), globally critically imperiled (G1), imperiled (G2), vulnerable (G3), or apparently secure (G4) in NatureServe. T denotes global listing at the infraspecific level. Number of accessions denotes active NPGS collections. Table from Khoury et al. (2017).



Figure 4. Pecos sunflower (*Helianthus paradoxus* Heiser) at Blue Hole Cienega, Santa Rosa, New Mexico. Pecos sunflower is a source of salt tolerance for cultivated sunflower, and is listed threatened under the Endangered Species Act and globally imperiled in NatureServe. Photo by Laura Marek, from Khoury et al. (2017).

Enhancing Existing Efforts on Crop Wild Relatives Through Collaborations

The USDA and partners are well-positioned to be able to “do the job” of comprehensively conserving and making available our important native crop wild relatives:

- The NPGS genebanks maintain high-quality conservation standards and are recognized for their customer service to the users of germplasm and associated information. The GRIN-Global online platform offers data critical to understanding the potential for breeding with native crop wild relatives and facilitates ordering of this germplasm. The curators of existing collections can receive, process, and distribute newly incorporated native wild relatives, given appropriate resources. Under the Plant Exploration Program, the NPGS manages a small annual competitive grant initiative supporting the collection of germplasm for the NPGS collections, including prioritizing crop wild relatives in the U.S. In collaboration with a well-equipped network of botanic gardens and other *ex situ* conservation institutions able and willing to safeguard and make available native genetic resources, the diversity of our prioritized native wild relatives can be collected and protected in conservation repositories, and made available to requestors
- USFS lands offer critically important habitat for a wide diversity of native crop wild relatives, particularly those occurring in the western U.S. Active monitoring and management of the populations of these wild cousins can be enacted, given adequate resources. In collaboration with other federal lands (BLM, Department of Defense,

National Park Service, etc.), state and local forests and parks, Native American lands, conservation organizations, and private entities which manage U.S. lands (*Figure 3*), integrated *in situ* conservation management plans for the diversity of our prioritized crop wild relatives can be created

- The ARS and USFS have a Memorandum of Understanding and a Strategic Framework on the Conservation and Use of Native Crop Wild Relatives in the United States. Under these arrangements, the Agencies are collaborating on conserving in the NPGS genebanks samples of wild relatives of cranberry collected on USFS lands, guided by ARS and academic genetic diversity research which will also enable USFS researchers to prioritize populations for active monitoring. The USFS Wild Chile Botanical Area, located in the Coronado National Forest in southern Arizona and the Cranberry Glades Botanical Area in West Virginia are the only protected natural areas in the country focused specifically on crop wild relatives. The USFS and ARS, with academic and nonprofit organization partners, are currently working on expanding the scope of the reserve so as to be cognizant of the other dozens of wild relatives also present. These projects represent excellent examples of the OneUSDA vision.
- The ARS performs research on crop wild relatives that is critical to the ‘value-adding’ of phenotypic, genotypic, and other information necessary for plant breeders and other requestors to efficiently and effectively use the germplasm. In collaboration with academic partners, these researchers have the capacity to fill the important data gaps for native wild relatives. USDA NIFA and other funding programs are institutionally organized to support such research through competitive calls. A recent effort coordinated by ARS researchers has brought together over 60 scientists to outline the conservation needs for North American crop wild relatives, including describing international collaboration benefits with our Canadian and Mexican counterparts with regard to species that occur in more than one country.
- The Department of Interior, Bureau of Land Management-led Seeds of Success (SOS) program has accumulated over 15 years of experience with federal and non-federal partners collecting wildland native seed for long-term germplasm conservation and for use in seed research, development of native plant materials, and ecosystem restoration. The collected materials are used in revegetation projects, while long-term conservation of samples and distribution to plant breeders and other researchers is handled by the NPGS. The program is interested in prioritizing crop wild relatives for collecting.
- The National Seed Strategy for Rehabilitation and Restoration, created by twelve federal agencies and over 300 non-federal cooperators outlined native seed collection, research, and land management needs for 2015-2020, including specifically targeting crop wild relatives. The USDA supports the Strategy through the work of ARS, USFS, NIFA, and the NRCS. A wider institutional framework for collaboration at the federal level is provided by the Plant Conservation Alliance (<https://www.blm.gov/programs/natural-resources/native-plant-communities/national-seed-strategy/pca>).

- The U.S. Fish and Wildlife Service provides federal protection for threatened and endangered plants, including native crop wild relatives, under the U.S. Endangered Species Act. Two nongovernmental organizations, NatureServe and the IUCN, provide threat-related information on U.S. flora, including crop wild relatives, which are important to prioritization setting.
- Many hundreds of botanical and public gardens are spread across the U.S. and serve important public education roles due to their accessibility to urban areas. Through a recent NIFA grant, the botanic garden network is deepening collaboration with ARS and other agricultural research organizations to better combat agriculture and plant “blindness”, and in particular to explain the value of crop wild relatives to the public.

Recommendations

Outlined below are the major components necessary to comprehensively conserve and make available our native heritage of crop wild relatives. We envision that many of the activities will be completed within a 5-year project timeframe, given funding estimated in *Annex 1*. Long-term maintenance activities will also require increased financial support, and these activities are also budgeted in the Annex. The National Genetic Resources Advisory Council recommends that USDA NPGS develop plans to implement these recommendations.

1. *Understand and document native crop wild relatives, assess threats to their natural habitats, and determine gaps in their conservation*

Conduct a comprehensive assessment of native crop wild relatives to target the highest priority species, understand their distributions and patterns of diversity, identify gaps in their conservation, and designate responsible parties to improve their state of conservation, both in *ex situ* repositories and in their natural habitats. This work has already been initiated, led by ARS researchers, but needs to be developed further. The analyses has been completed for the estimated 300 highest priority native wild relatives. From this study, plants comprising native close relatives of globally important agricultural crops as well as important wild food plants were categorized as Priority 1A (Khoury et al. 2020). These are listed in Annex 2. Pending work includes verification of outputs by professional and citizen scientists, wide distribution of results via scientific publications and information documents tailored to collectors, genebank curators, land managers, and other users; as well as entry into relevant conservation and genetic resources information platforms (e.g., NatureServe and GRIN-Global). (\$450,000 Years 1 and 2)

2. *Collect native wild relative populations not yet represented in the NPGS or other ex situ repositories (as plants, tissues or seeds)*

Initiate systematic collecting of prioritized crop wild relative populations across the U.S. Collecting should be coordinated by teams of botanic, taxonomic, and conservation experts, capitalizing on local botanical expertise, and provide training and educational opportunities for students and other collecting team members, including citizen scientists. The existing ARS Plant Exploration Program can serve as an appropriate structure for distributing funding, while the BLM-led Seeds of Success (SOS) program, which employs teams of interns yearly during the appropriate season to perform the collecting, offers a cost-effective model for the fieldwork. (\$2,700,000 Years 1-3)

3. *Make native crop wild relatives accessible to plant breeders, researchers, and educators*

Collect samples and associated information for repository conservation, process and make them available for distribution. Critical activities include cleaning and testing, multiplication of samples with few seeds, adding associated information into GRIN-Global and other public

databases, and distributing samples to requestors. Many of these activities can be achieved through training and utilization of citizen scientists. Processing and initial multiplication can be accomplished within the project timeframe, whereas ongoing support will be needed for long-term maintenance (including periodic regeneration) and distribution. (\$1,000,000 Years 2 – 5)

4. *Protect native crop wild relatives in their natural habitats*

Designation of habitat conservation sites for populations of the highest priority crop wild relatives in existing USFS and other federal and non-federal protected areas, and advocacy for the designation of additional protected areas, as needed to adequately protect the genetic diversity of these plants in their natural habitats. In addition, the protection of culturally significant plants used by indigenous communities for nutritional, medicinal, ceremonial, and other uses needs to be prioritized. As many of our native crop wild relatives are adapted to relatively disturbed habitats, opportunities also exist to work with producers to conserve wild relatives along hedgerows and other farm-level conservation sites. Activities include research into appropriate *in situ* conservation strategies, particularly for wild relatives that cannot be successfully conserved in conservation repositories, and formation of active management plans for conservation of priority populations. The research and initiation of management plans can be accomplished within the project timeframe. Ongoing support will be needed for long-term management by the USFS or other land managers. (\$900,000 Years 2 – 5)

5. *Raise public awareness about native crop wild relatives*

Create coordinated educational and communications programs to help raise awareness and provide a backdrop for the ongoing support of crop wild relative conservation and use, while respecting, preserving and maintaining associated indigenous and local knowledge, is necessary to the long term viability of conservation and plant breeding efforts. Skilled education and outreach professionals should lead collaborative efforts to raise awareness about the importance of, and threats to, our useful wild plants. (\$500,000 Years 1 – 5)

6. *Ongoing and long-term support*

Research support should also be made available for phenotypic, genotypic, and other characterizations and evaluations of native crop wild relatives, for pre-breeding activities, to provide added-value to public collections, for maintenance and distribution of germplasm and for *in situ* conservation of native crop wild relatives. Current NIFA SARE and other funding lines have very few opportunities for such ‘upstream’ research. Opportunities should be provided on an ongoing basis by expanding existing or by creating new NIFA strategic research calls so that wild relatives can be continuously explored, with the requirement that the results always be integrated into GRIN-Global or other appropriate publicly accessible repositories. (\$1,250,000 annually)

References

- Castañeda-Álvarez, N.P., C.K. Khoury, H.A. Achicanoy, V. Bernau, H. Dempewolf, R.J. Eastwood, L. Guarino, R.H. Harker, A. Jarvis, N. Maxted, J.V. Mueller, J. Ramírez-Villegas, C.C. Sosa, P.C. Struik, H. Vincent, and J. Toll. 2016. Global conservation priorities for crop wild relatives. *Nature Plants* 2(4):16022.
- Food and Agriculture Organization of the United Nations (FAO). 2010. *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture*. (Commission on Genetic Resources for Food and Agriculture, Food and Agriculture Organization of the United Nations).
- Greene, S.L., K.A Williams, C.K. Khoury, M.B. Kantar, and L.F. Marek (eds.) 2018a. *North American Crop Wild Relatives, Volume 1: Conservation Strategies*. Springer International Publishing AG, ISBN 978-3-319-95101-0. Doi: 10.1007/978-3-319-95101-0.
- Greene, S.L., K.A Williams, C.K. Khoury, M.B. Kantar, and L.F. Marek (eds.) 2019. *North American Crop Wild Relatives, Volume 2: Important Species*. Springer International Publishing AG, ISBN 978-3-319-97121-6. Doi: 10.1007/978-3-319-97121-6.
- Khoury, C.K., S. Greene, J. Wiersema, N. Maxted, A. Jarvis, and P.C. Struik. 2013. An inventory of crop wild relatives of the United States. *Crop Science* 53:1496.
- Khoury, C. K. S. L. Greene, K. A. Williams, C. C. Sosa, and C. Richards. 2017. Conservation Priorities for Tree Crop Wild Relatives in the United States. In: Sniezko *et al.* (tech. cords.) Gene conservation of tree species—banking on the future. Proceedings of a workshop. Gen. Tech. Rep. PNW-GTR-963. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 31-36.
- Khoury C. K., S. L. Greene, S. Krishnan, A. J. Miller, and T. Moreau. 2019. A Road Map for Conservation, Use, and Public Engagement around North America's Crop Wild Relatives and Wild Utilized Plants. *Crop Science* 59: 1-6. DOI: 10.2135/cropsci2019.05.0309.
- Khoury C.K., D. Carver, S. L. Greene, K. A. Williams, H. A. Achicanoy, B. León, J. H. Wiersema, and A. Frances. 2020. Crop wild relatives of the United States require urgent conservation action. Submitted
- USDA Forest Service, USDA Agricultural Research Service (2014) Joint Strategic Framework on the Conservation and Use of Native Crop Wild Relatives in the United States. <http://www.fs.fed.us/wildflowers/ethnobotany/documents/cwr/FrameworkNativeCropWildRelativesOct2014.pdf>
- Williams, K. A. and S. L. Greene. 2018. Conservation of Crop Wild Relatives in the USA. In: Greene *et al.* (eds.) *North American Crop Wild Relatives, Volume 1: Conservation Strategies*. Springer, doi: 10.1007/978-3-319-95101-0.

Annex 1: Activities and cost estimate for conserving and making accessible priority native crop wild relatives (Five-year project)

Activity	Output	Timeframe	Cost Estimate	Notes
1. Assess native crop wild relative conservation gaps in conservation repositories and in their natural habitats	Verified conservation gap analysis including identification of priority areas for enhancing conservation. Information published in scientific journals, in targeted information documents, and in online platforms	Y1 + Y2	\$450,000	USDA - \$150,000 staffing to supplement gap analysis team. \$20,000 within U.S. travel to herbaria and other data sources. \$30,000 -one stakeholder meeting. \$100,000 - NatureServe for full conservation threat assessment of populations <i>in situ</i> . \$100,000 - GRIN Taxonomy for progress on crop wild relative genepool assessments (potential value of wild relatives). \$50,000 ground-truthing and training with professional and citizen scientists
2. Collect native crop wild relatives for NPGS and other repository conservation	Prioritized underrepresented populations collected. Approximate: 300 priority taxa x 10 populations each to collect = 3,000 new accessions	Y1-Y3	\$2,700,000	USDA NPGS management through PEO and collecting teams with crop specific and taxonomic expert support such as experts from botanic gardens. Trained interns modeled per BLM SOS program. Cost- Kew estimates \$500/sample; SOS estimates \$1300/sample. Average = \$900/sample
3. Process collected samples for long-term <i>ex situ</i> conservation and distribution	Prioritized underrepresented populations and associated information processed, multiplied and banked in NPGS and other repositories for long-term conservation, and samples distributed via GRIN-Global	Y2-Y5	\$1,000,000	USDA NPGS and botanical gardens additional staffing and materials. SOS estimates \$350,000 annual cost for processing of 1500 collections per year, plus \$200,000 for seed storage management. Additional \$500,000 for USDA multiplication.
4. Designation of habitat conservation sites for populations of the highest priority crop wild relatives in existing protected areas, and advocacy for the designation of additional protected areas, as needed	Guidelines for management published, and management plans enacted for priority populations	Y2-Y5	\$900,000	USDA USFS with other federal as well as non-federal land managers. Stakeholder meeting \$50,000. Research into appropriate conservation strategies particularly for wild relatives that are not able to be successfully conserved in genebanks (\$50,000) and formation of active management plans for conservation of priority populations (\$800,000) (staffing, fieldwork)
5. Education and communication initiative	Coordinated outreach and education programs nationwide	Y1-Y5	\$500,000	USDA and botanic garden partners. Create informational materials and displays. Deploy across gardens, USFS facilities and other sites. Costs for staffing and materials.
Total			\$5,500,000	

Activity	Output	Timeframe	Cost Estimate	Notes
Ongoing/Long-term Support:				
Research for value-adding on native crop wild relatives	Characterization and evaluation data published and available via GRIN-Global and other repositories	Ongoing post-project	\$250,000 annually	Annual call for proposals via NIFA
6. Maintenance and distribution of crop wild relatives	Priority native crop wild relatives openly available for distribution by the NPGS	Ongoing post-project	\$500,000 annually	NPGS annual cost for performing periodic regeneration or multiplication of samples, covering ongoing costs for distribution
<i>In situ</i> conservation of native crop wild relatives	Priority native crop wild relatives actively managed in their natural habitats for the long-term	Ongoing post-project	\$500,000 annually	USFS and partners- annual cost for periodic assessments of populations and in some cases management interventions to encourage population viability
			\$1,250,000	
			Total annually	

Annex 2: Priority 1A taxa comprising native close relatives of globally important agricultural crops (including the taxa listed as primary or secondary relatives or used as root-/graft-stock), as well as important wild food plants (Khoury et al. 2020).

	Taxon	Associated crop type general	Associated crop type specific	Associated crop common name	Threat assessment status
1	<i>Acer saccharum</i>	Food	Sugars	Sugar maple	Possible Near Threatened (NT)
2	<i>Acer saccharum</i> subsp. <i>Floridanum</i>	Food	Sugars	Sugar maple	Vulnerable (VU)
3	<i>Acer saccharum</i> subsp. <i>leucoderme</i>	Food	Sugars	Sugar maple	Vulnerable (VU)
4	<i>Acer saccharum</i> subsp. <i>nigrum</i>	Food	Sugars	Sugar maple	Vulnerable (VU)
5	<i>Acer saccharum</i> subsp. <i>ozarkense</i>	Food	Sugars	Sugar maple	Critically Endangered (CR)
6	<i>Acer saccharum</i> subsp. <i>saccharum</i>	Food	Sugars	Sugar maple	Vulnerable (VU)
7	<i>Allium schoenoprasum</i> subsp. <i>schoenoprasum</i>	Food	Vegetables	Onion, garlic, chives, etc.	Vulnerable (VU)
8	<i>Allium tricoccum</i>	Food	Vegetables	Onion, garlic, chives, etc.	Vulnerable (VU)
9	<i>Annona montana</i>	Food	Fruits	Cherimoya	Critically Endangered (CR)
10	<i>Apios americana</i>	Food	Roots and tubers	Potato bean	Possible Near Threatened (NT)
11	<i>Artocarpus altilis</i>	Food	Fruits	Breadfruit, jackfruit	Endangered (EN)
12	<i>Artocarpus mariannensis</i>	Food	Fruits	Breadfruit, jackfruit	Critically Endangered (CR)
13	<i>Asimina triloba</i>	Food	Fruits	Paw paw	Possible Near Threatened (NT)
14	<i>Capsicum annuum</i> var. <i>glabriusculum</i>	Food	Vegetables	Chile pepper	Vulnerable (VU)
15	<i>Carya aquatica</i>	Food	Nuts	Pecan	Endangered (EN)
16	<i>Carya carolinae-septentrionalis</i>	Food	Nuts	Pecan	Endangered (EN)
17	<i>Carya cordiformis</i>	Food	Nuts	Pecan	Possible Near Threatened (NT)
18	<i>Carya floridana</i>	Food	Nuts	Pecan	Endangered (EN)
19	<i>Carya glabra</i>	Food	Nuts	Pecan	Possible Near Threatened (NT)
20	<i>Carya illinoensis</i>	Food	Nuts	Pecan	Vulnerable (VU)
21	<i>Carya laciniosa</i>	Food	Nuts	Pecan	Vulnerable (VU)
22	<i>Carya myristiciformis</i>	Food	Nuts	Pecan	Endangered (EN)
23	<i>Carya ovalis</i>	Food	Nuts	Pecan	Endangered (EN)

	Taxon	Associated crop type general	Associated crop type specific	Associated crop common name	Threat assessment status
24	<i>Carya ovata</i>	Food	Nuts	Pecan	Possible Near Threatened (NT)
25	<i>Carya pallida</i>	Food	Nuts	Pecan	Vulnerable (VU)
26	<i>Carya texana</i>	Food	Nuts	Pecan	Endangered (EN)
27	<i>Carya tomentosa</i>	Food	Nuts	Pecan	Possible Near Threatened (NT)
28	<i>Carya x lecontei</i>	Food	Nuts	Pecan	Critically Endangered (CR)
29	<i>Carya x ludoviciana</i>	Food	Nuts	Pecan	Critically Endangered (CR)
30	<i>Castanea dentata</i>	Food	Nuts	Chestnut	Vulnerable (VU)
31	<i>Castanea ozarkensis</i>	Food	Nuts	Chestnut	Endangered (EN)
32	<i>Castanea pumila</i>	Food	Nuts	Chestnut	Vulnerable (VU)
33	<i>Citrus depressa</i>	Food	Fruits	Citrus	Critically Endangered (CR)
34	<i>Corylus americana</i>	Food	Nuts	Hazelnut	Possible Near Threatened (NT)
35	<i>Corylus californica</i>	Food	Nuts	Hazelnut	Vulnerable (VU)
36	<i>Cucumis melo</i> var. <i>agrestis</i>	Food	Fruits	Melon	Critically Endangered (CR)
37	<i>Cucurbita okeechobeensis</i> subsp. <i>okeechobeensis</i>	Food	Fruits	Zucchini, squash, pumpkin, etc.	Endangered (EN)
38	<i>Cucurbita pepo</i> subsp. <i>ovifera</i> var. <i>ozarkana</i>	Food	Fruits	Zucchini, squash, pumpkin, etc.	Endangered (EN)
39	<i>Cucurbita pepo</i> subsp. <i>ovifera</i> var. <i>texana</i>	Food	Fruits	Zucchini, squash, pumpkin, etc.	Endangered (EN)
40	<i>Diospyros virginiana</i>	Food	Fruits	Persimmon	Possible Near Threatened (NT)
41	<i>Echinacea purpurea</i>	Medicinal	Medicinals	Echinacea	Vulnerable (VU)
42	<i>Ficus aurea</i>	Food	Fruits	Fig	Endangered (EN)
43	<i>Fragaria cascadiensis</i>	Food	Fruits	Strawberry	Endangered (EN)
44	<i>Fragaria chiloensis</i>	Food	Fruits	Strawberry	Vulnerable (VU)
45	<i>Fragaria chiloensis</i> subsp. <i>lucida</i>	Food	Fruits	Strawberry	Endangered (EN)
46	<i>Fragaria chiloensis</i> subsp. <i>pacifica</i>	Food	Fruits	Strawberry	Endangered (EN)
47	<i>Fragaria chiloensis</i> subsp. <i>sandwicensis</i>	Food	Fruits	Strawberry	Endangered (EN)
48	<i>Fragaria virginiana</i>	Food	Fruits	Strawberry	Least Concern (LC)
49	<i>Fragaria virginiana</i> subsp. <i>glauca</i>	Food	Fruits	Strawberry	Vulnerable (VU)

	Taxon	Associated crop type general	Associated crop type specific	Associated crop common name	Threat assessment status
50	<i>Fragaria virginiana</i> subsp. <i>grayana</i>	Food	Fruits	Strawberry	Endangered (EN)
51	<i>Fragaria virginiana</i> subsp. <i>platypetala</i>	Food	Fruits	Strawberry	Vulnerable (VU)
52	<i>Fragaria virginiana</i> subsp. <i>virginiana</i>	Food	Fruits	Strawberry	Vulnerable (VU)
53	<i>Fragaria x ananassa</i>	Food	Fruits	Strawberry	Vulnerable (VU)
54	<i>Fragaria x ananassa</i> nothosubsp. <i>cuneifolia</i>	Food	Fruits	Strawberry	Endangered (EN)
55	<i>Fragaria x bringhurstii</i>	Food	Fruits	Strawberry	Critically Endangered (CR)
56	<i>Gossypium hirsutum</i>	Material and industrial	Fibers	Cotton (upland)	Vulnerable (VU)
57	<i>Gossypium tomentosum</i>	Material and industrial	Fibers	Cotton (upland)	Endangered (EN)
58	<i>Helianthus annuus</i>	Food	Oils	Sunflower	Least Concern (LC)
59	<i>Helianthus anomalus</i>	Food	Oils	Sunflower	Endangered (EN)
60	<i>Helianthus argophyllus</i>	Food	Oils	Sunflower	Endangered (EN)
61	<i>Helianthus bolanderi</i>	Food	Oils	Sunflower	Vulnerable (VU)
62	<i>Helianthus debilis</i>	Food	Oils	Sunflower	Endangered (EN)
63	<i>Helianthus debilis</i> subsp. <i>cucumerifolius</i>	Food	Oils	Sunflower	Endangered (EN)
64	<i>Helianthus debilis</i> subsp. <i>debilis</i>	Food	Oils	Sunflower	Endangered (EN)
65	<i>Helianthus debilis</i> subsp. <i>silvestris</i>	Food	Oils	Sunflower	Endangered (EN)
66	<i>Helianthus debilis</i> subsp. <i>tardiflorus</i>	Food	Oils	Sunflower	Endangered (EN)
67	<i>Helianthus debilis</i> subsp. <i>vestitus</i>	Food	Oils	Sunflower	Endangered (EN)
68	<i>Helianthus deserticola</i>	Food	Oils	Sunflower	Endangered (EN)
69	<i>Helianthus exilis</i>	Food	Oils	Sunflower	Endangered (EN)
70	<i>Helianthus neglectus</i>	Food	Oils	Sunflower	Endangered (EN)
71	<i>Helianthus niveus</i>	Food	Oils	Sunflower	Endangered (EN)
72	<i>Helianthus niveus</i> subsp. <i>canescens</i>	Food	Oils	Sunflower	Endangered (EN)
73	<i>Helianthus niveus</i> subsp. <i>tephrodes</i>	Food	Oils	Sunflower	Endangered (EN)
74	<i>Helianthus paradoxus</i>	Food	Oils	Sunflower	Endangered (EN)
75	<i>Helianthus petiolaris</i>	Food	Oils	Sunflower	Possible Near Threatened (NT)
76	<i>Helianthus petiolaris</i> subsp. <i>fallax</i>	Food	Oils	Sunflower	Vulnerable (VU)
77	<i>Helianthus petiolaris</i> subsp. <i>petiolaris</i>	Food	Oils	Sunflower	Endangered (EN)
78	<i>Helianthus praecox</i>	Food	Oils	Sunflower	Endangered (EN)

	Taxon	Associated crop type general	Associated crop type specific	Associated crop common name	Threat assessment status
79	<i>Helianthus praecox</i> subsp. <i>hirtus</i>	Food	Oils	Sunflower	Endangered (EN)
80	<i>Helianthus praecox</i> subsp. <i>praecox</i>	Food	Oils	Sunflower	Endangered (EN)
81	<i>Helianthus praecox</i> subsp. <i>runyonii</i>	Food	Oils	Sunflower	Endangered (EN)
82	<i>Helianthus resinosus</i>	Food	Oils	Sunflower	Endangered (EN)
83	<i>Helianthus tuberosus</i>	Food	Oils	Sunflower	Possible Near Threatened (NT)
84	<i>Helianthus winteri</i>	Food	Oils	Sunflower	Critically Endangered (CR)
85	<i>Humulus lupulus</i>	Food	Spices	Hop	Vulnerable (VU)
86	<i>Humulus lupulus</i> var. <i>lupuloides</i>	Food	Spices	Hop	Endangered (EN)
87	<i>Humulus lupulus</i> var. <i>neomexicanus</i>	Food	Spices	Hop	Vulnerable (VU)
88	<i>Humulus lupulus</i> var. <i>pubescens</i>	Food	Spices	Hop	Endangered (EN)
89	<i>Ipomoea littoralis</i>	Food	Roots and tubers	Sweetpotato	Endangered (EN)
90	<i>Ipomoea trifida</i>	Food	Roots and tubers	Sweetpotato	Endangered (EN)
91	<i>Juglans californica</i>	Food	Nuts	Walnut	Vulnerable (VU)
92	<i>Juglans cinerea</i>	Food	Nuts	Walnut	Vulnerable (VU)
93	<i>Juglans hindsii</i>	Food	Nuts	Walnut	Vulnerable (VU)
94	<i>Juglans major</i>	Food	Nuts	Walnut	Vulnerable (VU)
95	<i>Juglans major</i> var. <i>major</i>	Food	Nuts	Walnut	Vulnerable (VU)
96	<i>Juglans microcarpa</i>	Food	Nuts	Walnut	Endangered (EN)
97	<i>Juglans microcarpa</i> var. <i>microcarpa</i>	Food	Nuts	Walnut	Endangered (EN)
98	<i>Juglans nigra</i>	Food	Nuts	Walnut	Possible Near Threatened (NT)
99	<i>Malus fusca</i>	Food	Fruits	Apple	Vulnerable (VU)
100	<i>Oryza latifolia</i>	Food	Cereals and pseudocereals	Rice	Endangered (EN)
101	<i>Panicum virgatum</i>	Forage and feed	Forages and feeds	Switchgrass	Least Concern (LC)
102	<i>Phaseolus acutifolius</i>	Food	Pulses	Lima bean, tepary bean	Possible Near Threatened (NT)
103	<i>Phaseolus acutifolius</i> var. <i>acutifolius</i>	Food	Pulses	Lima bean, tepary bean	Endangered (EN)
104	<i>Phaseolus acutifolius</i> var. <i>tenuifolius</i>	Food	Pulses	Lima bean, tepary bean	Endangered (EN)
105	<i>Pistacia texana</i>	Food	Nuts	Pistachio	Endangered (EN)
106	<i>Prunus americana</i>	Food	Fruits	Almond, cherry, peach, etc.	Possible Near Threatened (NT)

	Taxon	Associated crop type general	Associated crop type specific	Associated crop common name	Threat assessment status
107	<i>Prunus angustifolia</i>	Food	Fruits	Almond, cherry, peach, etc.	Vulnerable (VU)
108	<i>Prunus emarginata</i>	Food	Fruits	Almond, cherry, peach, etc.	Least Concern (LC)
109	<i>Prunus geniculata</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
110	<i>Prunus gracilis</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
111	<i>Prunus hortulana</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
112	<i>Prunus maritima</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
113	<i>Prunus mexicana</i>	Food	Fruits	Almond, cherry, peach, etc.	Vulnerable (VU)
114	<i>Prunus murrayana</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
115	<i>Prunus nigra</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
116	<i>Prunus pensylvanica</i>	Food	Fruits	Almond, cherry, peach, etc.	Possible Near Threatened (NT)
117	<i>Prunus pumila</i>	Food	Fruits	Almond, cherry, peach, etc.	Vulnerable (VU)
118	<i>Prunus pumila var. besseyi</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
119	<i>Prunus pumila var. depressa</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
120	<i>Prunus pumila var. pumila</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
121	<i>Prunus pumila var. susquehanae</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
122	<i>Prunus rivularis</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
123	<i>Prunus subcordata</i>	Food	Fruits	Almond, cherry, peach, etc.	Vulnerable (VU)

	Taxon	Associated crop type general	Associated crop type specific	Associated crop common name	Threat assessment status
124	<i>Prunus texana</i>	Food	Fruits	Almond, cherry, peach, etc.	Endangered (EN)
125	<i>Prunus umbellata</i>	Food	Fruits	Almond, cherry, peach, etc.	Vulnerable (VU)
126	<i>Psidium guajava</i>	Food	Fruits	Guava	Vulnerable (VU)
127	<i>Ribes americanum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
128	<i>Ribes aureum</i>	Food	Fruits	Currant, gooseberry	Least Concern (LC)
129	<i>Ribes aureum</i> var. <i>aureum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
130	<i>Ribes aureum</i> var. <i>gracillimum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
131	<i>Ribes aureum</i> var. <i>villosum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
132	<i>Ribes binominatum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
133	<i>Ribes bracteosum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
134	<i>Ribes californicum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
135	<i>Ribes californicum</i> var. <i>hesperium</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
136	<i>Ribes cereum</i>	Food	Fruits	Currant, gooseberry	Least Concern (LC)
137	<i>Ribes cereum</i> var. <i>cereum</i>	Food	Fruits	Currant, gooseberry	Possible Near Threatened (NT)
138	<i>Ribes cereum</i> var. <i>colubrinum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
139	<i>Ribes curvatum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
140	<i>Ribes cynosbati</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
141	<i>Ribes divaricatum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
142	<i>Ribes echinellum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
143	<i>Ribes hirtellum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
144	<i>Ribes hudsonianum</i>	Food	Fruits	Currant, gooseberry	Possible Near Threatened (NT)
145	<i>Ribes hudsonianum</i> var. <i>hudsonianum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
146	<i>Ribes hudsonianum</i> var. <i>petiolare</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
147	<i>Ribes indecorum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
148	<i>Ribes inerme</i>	Food	Fruits	Currant, gooseberry	Possible Near Threatened (NT)
149	<i>Ribes lasianthum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
150	<i>Ribes laxiflorum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
151	<i>Ribes leptanthum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)

	Taxon	Associated crop type general	Associated crop type specific	Associated crop common name	Threat assessment status
152	<i>Ribes lobbii</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
153	<i>Ribes malvaceum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
154	<i>Ribes malvaceum</i> var. <i>malvaceum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
155	<i>Ribes malvaceum</i> var. <i>viridifolium</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
156	<i>Ribes marshallii</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
157	<i>Ribes menziesii</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
158	<i>Ribes mescalegium</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
159	<i>Ribes missouriense</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
160	<i>Ribes montigenum</i>	Food	Fruits	Currant, gooseberry	Least Concern (LC)
161	<i>Ribes nevadense</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
162	<i>Ribes niveum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
163	<i>Ribes oxyacanthoides</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
164	<i>Ribes oxyacanthoides</i> subsp. <i>cognatum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
165	<i>Ribes oxyacanthoides</i> subsp. <i>hendersonii</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
166	<i>Ribes oxyacanthoides</i> subsp. <i>irriguum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
167	<i>Ribes oxyacanthoides</i> subsp. <i>oxyacanthoides</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
168	<i>Ribes oxyacanthoides</i> subsp. <i>setosum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
169	<i>Ribes pinetorum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
170	<i>Ribes quercetorum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
171	<i>Ribes roezlii</i>	Food	Fruits	Currant, gooseberry	Possible Near Threatened (NT)
172	<i>Ribes roezlii</i> var. <i>amictum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
173	<i>Ribes roezlii</i> var. <i>cruentum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
174	<i>Ribes roezlii</i> var. <i>roezlii</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
175	<i>Ribes rotundifolium</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
176	<i>Ribes sanguineum</i>	Food	Fruits	Currant, gooseberry	Possible Near Threatened (NT)
177	<i>Ribes sanguineum</i> var. <i>glutinosum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
178	<i>Ribes sanguineum</i> var. <i>sanguineum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
179	<i>Ribes sericeum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
180	<i>Ribes speciosum</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
181	<i>Ribes thacherianum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)

	Taxon	Associated crop type general	Associated crop type specific	Associated crop common name	Threat assessment status
182	<i>Ribes triste</i>	Food	Fruits	Currant, gooseberry	Possible Near Threatened (NT)
183	<i>Ribes tulareense</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
184	<i>Ribes velutinum</i>	Food	Fruits	Currant, gooseberry	Possible Near Threatened (NT)
185	<i>Ribes viburnifolium</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
186	<i>Ribes viscosissimum</i>	Food	Fruits	Currant, gooseberry	Least Concern (LC)
187	<i>Ribes watsonianum</i>	Food	Fruits	Currant, gooseberry	Endangered (EN)
188	<i>Ribes wolfii</i>	Food	Fruits	Currant, gooseberry	Vulnerable (VU)
189	<i>Rubus allegheniensis</i>	Food	Fruits	Raspberry, blackberry	Possible Near Threatened (NT)
190	<i>Rubus arcticus</i>	Food	Fruits	Raspberry, blackberry	Possible Near Threatened (NT)
191	<i>Rubus arcticus</i> subsp. <i>acaulis</i>	Food	Fruits	Raspberry, blackberry	Vulnerable (VU)
192	<i>Rubus arcticus</i> subsp. <i>arcticus</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)
193	<i>Rubus arcticus</i> subsp. <i>stellatus</i>	Food	Fruits	Raspberry, blackberry	Vulnerable (VU)
194	<i>Rubus argutus</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)
195	<i>Rubus baileyanus</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)
196	<i>Rubus canadensis</i>	Food	Fruits	Raspberry, blackberry	Vulnerable (VU)
197	<i>Rubus chamaemorus</i>	Food	Fruits	Raspberry, blackberry	Possible Near Threatened (NT)
198	<i>Rubus cuneifolius</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)
199	<i>Rubus deliciosus</i>	Food	Fruits	Raspberry, blackberry	Vulnerable (VU)
200	<i>Rubus flagellaris</i>	Food	Fruits	Raspberry, blackberry	Vulnerable (VU)
201	<i>Rubus hawaiiensis</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)
202	<i>Rubus hispidus</i>	Food	Fruits	Raspberry, blackberry	Vulnerable (VU)
203	<i>Rubus hispidus</i> var. <i>obovalis</i>	Food	Fruits	Raspberry, blackberry	Critically Endangered (CR)
204	<i>Rubus idaeus</i>	Food	Fruits	Raspberry, blackberry	Possible Near Threatened (NT)
205	<i>Rubus idaeus</i> subsp. <i>strigosus</i>	Food	Fruits	Raspberry, blackberry	Possible Near Threatened (NT)
206	<i>Rubus leucodermis</i>	Food	Fruits	Raspberry, blackberry	Possible Near Threatened (NT)
207	<i>Rubus neglectus</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)

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208	<i>Rubus neomexicanus</i>	Food	Fruits	Raspberry, blackberry	Vulnerable (VU)
209	<i>Rubus nivalis</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)
210	<i>Rubus nutkanus</i>	Food	Fruits	Raspberry, blackberry	Least Concern (LC)
211	<i>Rubus occidentalis</i>	Food	Fruits	Raspberry, blackberry	Possible Near Threatened (NT)
212	<i>Rubus odoratus</i>	Food	Fruits	Raspberry, blackberry	Vulnerable (VU)
213	<i>Rubus parviflorus</i>	Food	Fruits	Raspberry, blackberry	Critically Endangered (CR)
214	<i>Rubus riograndis</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)
215	<i>Rubus spectabilis</i>	Food	Fruits	Raspberry, blackberry	Possible Near Threatened (NT)
216	<i>Rubus trivialis</i>	Food	Fruits	Raspberry, blackberry	Vulnerable (VU)
217	<i>Rubus ursinus</i>	Food	Fruits	Raspberry, blackberry	Possible Near Threatened (NT)
218	<i>Rubus ursinus</i> subsp. <i>macropetalus</i>	Food	Fruits	Raspberry, blackberry	Vulnerable (VU)
219	<i>Rubus ursinus</i> subsp. <i>ursinus</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)
220	<i>Rubus vermontanus</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)
221	<i>Rubus x neglectus</i>	Food	Fruits	Raspberry, blackberry	Endangered (EN)
222	<i>Solanum stoloniferum</i>	Food	Roots and tubers	Potato, eggplant, tomato	Possible Near Threatened (NT)
223	<i>Vaccinium angustifolium</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)
224	<i>Vaccinium arboreum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)
225	<i>Vaccinium boreale</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
226	<i>Vaccinium caesariense</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
227	<i>Vaccinium calycinum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
228	<i>Vaccinium cespitosum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)
229	<i>Vaccinium corymbosum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)

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230	<i>Vaccinium darrowii</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Vulnerable (VU)
231	<i>Vaccinium deliciosum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Vulnerable (VU)
232	<i>Vaccinium dentatum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
233	<i>Vaccinium elliotii</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Vulnerable (VU)
234	<i>Vaccinium formosum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
235	<i>Vaccinium fuscatum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Vulnerable (VU)
236	<i>Vaccinium hirsutum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
237	<i>Vaccinium macrocarpon</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Vulnerable (VU)
238	<i>Vaccinium membranaceum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)
239	<i>Vaccinium myrsinites</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
240	<i>Vaccinium myrtilloides</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Vulnerable (VU)
241	<i>Vaccinium myrtilus</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Vulnerable (VU)
242	<i>Vaccinium ovalifolium</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)
243	<i>Vaccinium ovalifolium</i> var. <i>ovalifolium</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)
244	<i>Vaccinium oxycoccos</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)
245	<i>Vaccinium pallidum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)

	Taxon	Associated crop type general	Associated crop type specific	Associated crop common name	Threat assessment status
246	<i>Vaccinium parvifolium</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)
247	<i>Vaccinium reticulatum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
248	<i>Vaccinium scoparium</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Least Concern (LC)
249	<i>Vaccinium simulatum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
250	<i>Vaccinium stamineum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)
251	<i>Vaccinium tenellum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
252	<i>Vaccinium uliginosum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Least Concern (LC)
253	<i>Vaccinium virgatum</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Endangered (EN)
254	<i>Vaccinium vitis-idaea</i>	Food	Fruits	Blueberry, cranberry, lingonberry	Possible Near Threatened (NT)
255	<i>Vanilla mexicana</i>	Food	Spices	Vanilla	Critically Endangered (CR)
256	<i>Vanilla phaeantha</i>	Food	Spices	Vanilla	Critically Endangered (CR)
257	<i>Vanilla planifolia</i>	Food	Spices	Vanilla	Endangered (EN)
258	<i>Vitis acerifolia</i>	Food	Fruits	Grape	Endangered (EN)
259	<i>Vitis aestivalis</i>	Food	Fruits	Grape	Vulnerable (VU)
260	<i>Vitis arizonica</i>	Food	Fruits	Grape	Possible Near Threatened (NT)
261	<i>Vitis californica</i>	Food	Fruits	Grape	Vulnerable (VU)
262	<i>Vitis cinerea</i>	Food	Fruits	Grape	Vulnerable (VU)
263	<i>Vitis cinerea</i> var. <i>helleri</i>	Food	Fruits	Grape	Endangered (EN)
264	<i>Vitis cinerea</i> var. <i>tomentosa</i>	Food	Fruits	Grape	Critically Endangered (CR)
265	<i>Vitis monticola</i>	Food	Fruits	Grape	Endangered (EN)
266	<i>Vitis mustangensis</i>	Food	Fruits	Grape	Endangered (EN)
267	<i>Vitis riparia</i>	Food	Fruits	Grape	Possible Near Threatened (NT)

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267	<i>Vitis rotundifolia</i>	Food	Fruits	Grape	Vulnerable (VU)
269	<i>Vitis rotundifolia</i> var. <i>munsoniana</i>	Food	Fruits	Grape	Endangered (EN)
270	<i>Vitis rotundifolia</i> var. <i>rotundifolia</i>	Food	Fruits	Grape	Endangered (EN)
271	<i>Vitis rupestris</i>	Food	Fruits	Grape	Endangered (EN)
272	<i>Vitis shuttleworthii</i>	Food	Fruits	Grape	Endangered (EN)
273	<i>Vitis tiliifolia</i>	Food	Fruits	Grape	Endangered (EN)
274	<i>Vitis treleasei</i>	Food	Fruits	Grape	Critically Endangered (CR)
275	<i>Vitis vulpina</i>	Food	Fruits	Grape	Possible Near Threatened (NT)
276	<i>Vitis x champinii</i>	Food	Fruits	Grape	Critically Endangered (CR)
277	<i>Vitis x slavinii</i>	Food	Fruits	Grape	Critically Endangered (CR)
278	<i>Xanthosoma sagittifolium</i>	Food	Roots and tubers	Xanthosoma	Endangered (EN)
279	<i>Zizania aquatica</i>	Food	Cereals and pseudocereals	Wildrice	Vulnerable (VU)
280	<i>Zizania aquatica</i> var. <i>aquatica</i>	Food	Cereals and pseudocereals	Wildrice	Endangered (EN)
281	<i>Zizania palustris</i>	Food	Cereals and pseudocereals	Wildrice	Endangered (EN)
282	<i>Zizania palustris</i> var. <i>interior</i>	Food	Cereals and pseudocereals	Wildrice	Endangered (EN)
283	<i>Zizania palustris</i> var. <i>palustris</i>	Food	Cereals and pseudocereals	Wildrice	Endangered (EN)
284	<i>Zizania texana</i>	Food	Cereals and pseudocereals	Wildrice	Critically Endangered (CR)