

A Road Map for Conservation, Use, and Public Engagement around North America's Crop Wild Relatives and Wild Utilized Plants

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ABSTRACT

Crop wild relatives—the plant species closely related to agricultural crops—are valuable genetic resources used by plant breeders to increase pest and disease resistance, stress tolerance, nutritional profile, and other traits critical to productivity, quality, and sustainability. Wild utilized plants provide food and a variety of other ecosystem and cultural services to people. North America harbors a rich native flora that includes wild relatives of important food, fiber, industrial, feed and forage, medicinal, and ornamental crops, as well as a diversity of regionally significant wild utilized plants. Many of these species are threatened in their natural habitats, and most are underrepresented in plant genebanks and botanical gardens. These conservation gaps limit the portfolio of useful plant diversity available to present and future generations. Likewise, the myriad potential uses of North American crop wild relatives and wild utilized plants are underexplored, and public awareness of their value and threats is limited. Greater coordination of efforts among plant conservation, land management, agricultural science, and botanical education and outreach organizations will be necessary to secure, enhance use, and raise awareness with regard to these species. A road map for collaborative action is presented here, focused on five priorities: (i) to understand and document North America's crop wild relatives and wild utilized plants, (ii) to protect threatened species in their natural habitats, (iii) to collect and conserve *ex situ* the diversity of prioritized species, (iv) to make this diversity accessible and attractive for plant breeding, research, and education, and (v) to raise public awareness of their value and the threats to their persistence.

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INCREASING the productivity, nutritional quality, and sustainability of food systems is essential to nourish humanity in the decades to come (Foley et al., 2011; Godfray et al., 2010; Tilman et al., 2011). Mitigating profound declines in plant biodiversity will be critical to the resilience of natural systems and to the provision of ecosystem services (Brummitt et al., 2015; Newbold et al., 2015; Rockström et al., 2009).

These food system and conservation priorities converge with crop wild relatives and wild utilized plant species. Many crop wild relatives—the wild progenitors and other plant species closely related to cultivated plants—are resistant to the pests and diseases that cause crop losses, are adapted to extreme climates or difficult soils, or possess other valuable agronomic or nutritional characteristics (Dempewolf et al., 2017; Hajjar and Hodgkin, 2007). Due to the close genetic relationship of wild relatives with the cultivated species, useful productivity, nutrition, and sustainability traits found in wild relatives can be bred into crops. In addition, crop wild relatives serve important roles in domestication and evolution research (Doebley et al., 2006; Larson et al., 2014; Meyer and Purugganan, 2013), and some are themselves attractive candidates for future domestication (Ciotir et al., 2019).

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Wild utilized plant species, meanwhile, are noncultivated plants that are wild harvested for human nutrition and cultural uses (Cruz-García and Price, 2014; Gascon et al., 2015; Willis, 2017).

The natural populations of many crop wild relatives and wild utilized plant species are threatened by habitat destruction and degradation, invasive species, climate change, pollution, or overharvesting (Brummitt et al., 2015; Jarvis et al., 2008; Khoury et al., 2019). At the same time, the majority are poorly represented in plant genebanks and botanical gardens (Castañeda-Álvarez et al., 2016; Khoury et al., 2019). Urgent conservation action is required if they are to be available for use in the future.

North America has a rich flora of wild relatives of agricultural and horticultural crops, including wild apples (*Malus* Mill.), beans (*Phaseolus* L.), blueberries and cranberries (*Vaccinium* L.), chile peppers (*Capsicum* L.), corn (*Zea* L. and *Tripsacum* L.), cotton (*Gossypium* L.), grapes (*Vitis* L.), hops (*Humulus* L.), onions (*Allium* L.), pumpkins (*Cucurbita* L.), sunflowers (*Helianthus* L.), and many more (Contreras-Toledo et al., 2018; Greene et al., 2018b, 2019; Khoury et al., 2013). The region is also home to a diversity of significant wild utilized plants such as sugar maple (*Acer saccharum* Marshall) and wildrice (*Zizania palustris* L.).

The natural habitats of many North American crop wild relative and wild utilized plant populations are degraded or are disappearing, and most species lack sufficient representation in genebanks, botanical gardens, and other ex situ repositories (Greene et al., 2018b, 2019; Zhang et al., 2017). The majority have been only superficially documented, if at all, with regard to their potential breeding utility (Dempewolf et al., 2017). Moreover, their value as well as threats to their survival are largely unknown to the public (Krishnan et al., 2019).

Efforts are underway in many world regions to conserve crop wild relatives and wild utilized plants, as discussed in international fora (CBD, 2010a, 2010b; FAO, 2002; United Nations, 2015). In planning a global conservation initiative for wild relatives (Dempewolf et al., 2014), North America was recognized as an important hotspot, with many valuable native species inadequately safeguarded (Castañeda-Álvarez et al., 2016). Identifying and addressing conservation gaps for North American crop wild relatives and wild utilized plants, facilitating their use in plant breeding, and educating the scientific and general public regarding their value as well as the threats to their survival are all urgently needed. Accomplishing these daunting, interconnected goals will require partnerships and collaborations across plant conservation, land management, agricultural science, and botanical education and outreach organizations, institutions, and stakeholders.

Organizations across Canada, Mexico, and the United States are striving toward, or have expressed interest in, increasing the contribution of native wild species to food

and nutrition security and to the sustainability of production systems. Conservation organizations are actively working to document the current state of protection of wild relatives (Frances et al., 2018). Land management agencies are responsible for balancing multiple use priorities over large portions of North America (IUCN, 2019). Public genebanks make plant genetic diversity openly accessible to scientists, plant breeders, and educators (Gepts, 2006; Hoisington et al., 1999). Plant research institutions have diverse and complementary capacities in crop improvement (Byrne et al., 2018; Repinski et al., 2011). Almost 1000 botanical and public gardens are located across North America, educating visitors and performing important conservation and research activities (BGCI, 2016; Krishnan and Novy, 2016; Miller et al., 2015). Collaborations across these institutions are growing, focused on important species such as wild chile peppers (USDA-FS, 2016a) and cranberries (USDA-FS, 2016b). A variety of existing institutional frameworks and agreements facilitate work between organizations and across borders (BGCI, 2016; FAO, 2002; Greene et al., 2018a; Haidet and Olwell, 2015; Plant Conservation Alliance, 2017; USDA-FS and USDA-ARS, 2014).

A road map for conservation, use, and public engagement around North America's crop wild relatives and wild utilized plants was developed as part of "Celebrating Crop Diversity: Connecting Agriculture, Public Gardens and Science," a USDA National Institute of Food and Agriculture (USDA- NIFA), US Botanic Garden, Leightag Foundation, and World Food Prize Foundation sponsored project run jointly by the Alliance of Crop, Soil, and Environmental Science Societies (ACSESS) and the American Public Garden Association (APGA). The road map was refined and improved with input from a wide range of agricultural and botanical researchers, scientists, plant breeders, and educators, both through online surveys and during in-person stakeholder consultations at the World Food Prize Foundation in Des Moines, IA, 2 to 4 Apr. 2019.

A ROAD MAP FOR NORTH AMERICAN CROP WILD RELATIVES AND WILD UTILIZED PLANTS

To accomplish the goals of enhanced conservation, facilitated use, and increased public awareness of North America's crop wild relatives and wild utilized plants, a diversity in capacities and approaches will be needed, with partnerships among plant conservation, land management, agricultural science, and botanical education and outreach organizations aimed at (i) understanding and documenting North America's crop wild relatives and wild utilized plants, (ii) protecting threatened species in their natural habitats, (iii) collecting and conserving ex situ the diversity of prioritized species, (iv) making this diversity

accessible and attractive for plant breeding, research, and education, and (v) raising public awareness of their value and the threats to their persistence.

1. Understand and document North America's crop wild relatives and wild utilized plants, assess threats to their natural habitats, and determine gaps in their conservation. Species inventories and conservation assessments have been generated for various taxa and for some geographic regions in North America (e.g., Castañeda-Álvarez et al., 2015; Contreras-Toledo et al., 2018; Greene et al., 2019; Kantar et al., 2015; Khoury et al., 2013, 2015; Wiersema et al., 2012), but many land management areas have no comprehensive species lists, and for many species, assessments are either out of date or have not yet been performed (Frances et al., 2018).

Assessments are needed to further document and define the highest priority species across North America, understand spatial patterns with regard to their genetic diversity, analyze threats to populations, and identify the most important gaps in conservation. Further recognizing North American wild plant species with potential future agricultural significance is also a priority. Results should be integrated into relevant information platforms used by the conservation, land management, genetic resource, and agricultural research communities (e.g., BGCI, 2019; CONABIO, 2019; NatureServe, 2019; USDA-ARS NPGS, 2019), and these platforms should more easily align. The information and priorities must be shared widely with professionals in the conservation, land management, agricultural science, and outreach communities, as well as with the public.

2. Protect North America's crop wild relatives and wild utilized plants in their natural habitats. North America's public, private, military, Indigenous and First Peoples', and other open spaces conserve numerous crop wild relative and wild utilized plant populations collaterally, because of overall land protection practices. These plants are not explicitly prioritized except in a few exceptional cases (e.g., for some chile pepper [USDA-FS, 2016a], cranberry [USDA-FS, 2016b], and maize [De La Torre et al., 2018] wild relative populations). Most species are not currently sufficiently conserved in their natural habitats (Khoury et al., 2019).

Conservation sites covering populations of the highest priority and/or the most threatened crop wild relatives and wild utilized plants need to be designated in existing protected areas, and additional protected areas might need to be considered, to adequately protect the genetic diversity of these plants in their natural habitats so they can continue to evolve. Conservation of priority species that occurs collaterally within multiple land use areas should be upgraded to active management with the aim of ensuring

the viability of populations for the long term, including under the pressures of climate change. To do so, priorities for species conservation will need to be expanded beyond those few currently officially listed as threatened and endangered. As some native crop wild relatives and wild utilized plants are adapted to relatively disturbed habitats, opportunities also exist to work with farmers and other landowners to protect these species in hedgerows, conservation easements, and other open spaces.

3. Collect and conserve North America's prioritized crop wild relatives and wild utilized plants in ex situ collections. Ex situ collections of important crop wild relatives and wild utilized plants are maintained in public genebanks and botanical gardens across North America, but these collections are not currently complete with regard to coverage of taxa, nor to genetic diversity within species (Castañeda-Álvarez et al., 2016; Greene et al., 2018b, 2019; Khoury et al., 2019).

Prioritized crop wild relatives and wild utilized plants across North America need further collecting for ex situ conservation. This will require coordination by botanical, taxonomic, and conservation experts, capitalizing on local botanical expertise, while hopefully also providing much needed training and educational opportunities for additional participants (Kramer et al., 2013). The plants then need to be processed and stored in plant genebanks and botanical gardens under conditions that will enable their survival for the long term. Further research is needed to develop techniques for the maintenance of species that currently require expensive, nonstandard approaches.

4. Make North America's crop wild relatives and wild utilized plants accessible and attractive to plant breeders, researchers, and educators. North America's public genebanks, botanical gardens, and open spaces provide the foundation for making crop wild relatives and wild utilized plants accessible for research and education. In the genebanks and conservation facilities in botanical gardens, these plants need to be carefully managed to ensure adequate, high-quality, true-to-type propagules are available for distribution, and they need to be easily accessible via online databases. Indigenous, traditional, and local knowledge about these plants must be valued and protected through access provided by agreements based on mutually agreed terms. These plants should also be accessible to the public through botanical garden displays and through information initiatives on public lands. To make this diversity more attractive for crop improvement, wild relatives of high potential value should be characterized and evaluated for traits of interest, with these data maintained and accessible alongside the germplasm. Crop wild relative genotypes of high potential value should then be prebred with domesticated

germplasm to facilitate the generation of breeding lines of interest to plant breeders (Prohens et al., 2017).

5. Raise public awareness about North America's crop wild relatives and wild utilized plants.

Plant conservation, land management, and agricultural science organizations are all increasing their efforts to communicate the value of plants and the many threats to their persistence, recognizing the critical need for continued public awareness and support for conservation and for agricultural research (Krishnan et al., 2019). Creating coordinated educational and communications programs to help raise awareness and provide a backdrop for support of crop wild relative and wild utilized plant conservation is necessary for 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, North American crop wild relatives and wild utilized plants.

These five priorities are interdependent and require collaborative, coordinated efforts. Current initiatives that combine the efforts of land managers, agricultural researchers, botanical gardens, and other organizations for the conservation and use of wild cranberries and other crop wild relatives are demonstrating the value of collaborative approaches (USDA-FS, 2016b). Through partnerships, significant progress could be made in conservation, use, and public engagement around North American crop wild relatives and wild utilized plants.

Conflict of Interest

The authors declare that there is no conflict of interest.

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