Published August 30, 2018

OPINION & POLICY

2017 Frank Meyer Medal for Plant Genetic Resources Lecture: Stewards of Our Agricultural Future

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ABSTRACT

Humanity's survival depends on crops—the green line standing between us and calamity. To meet ever expanding human needs, crops must become increasingly more productive, mainly through genetic gains that exploit diverse plant genetic resources (PGR), the raw materials for crop breeding. For millennia, PGR have been conserved by individuals, communities, and organizations. These stewards of our agricultural future have been nearly as diverse as the PGR that they have conserved. Their invaluable roles in underpinning the security of global agriculture have largely been underappreciated. Furthermore, the challenges and complexity of successful PGR stewardship have been inadequately recognized. This paper pays tribute to these stewards' characteristic attributes and their contributions to PGR conservation and sustainable use. It describes the pervasive impacts of PGR on crop agriculture and explains how numerous factors have affected PGR stewardship capacities. Plant genetic resource stewardship involves many different components, which are typically conducted over extended timeframes. Sustained, adequate support for PGR maintenance, a key component, has been the exception rather than the rule. Past and present PGR stewardship successes and challenges furnish numerous lessons for meeting future demands. Such lessons include recognizing the importance to PGR stewardship of: dedicated and diverse PGR stewards, continual and persistent financial support for PGR genebanks and their staffs, protecting crop wild relatives, and safeguarding genebank collections from extreme weather and introduced pests and pathogens. In the future, PGR stewardship might be conducted more frequently and more adequately by multi-institutional networks enabled by advances in information technology and artificial intelligence.

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Abbreviations: AI, artificial intelligence; CGIAR, Consultative Group for International Agricultural Research; CWR, crop wild relative(s); GCDT, Global Crop Diversity Trust; GRIN, Germplasm Resources Information Network; IICA, Instituto Interamericano de Cooperacíon para la Agricultura; ITPGRFA, International Treaty on Plant Genetic Resources for Food and Agriculture; NLGRP, National Laboratory for Genetic Resources Preservation; NPGS, National Plant Germplasm System; PGR, plant genetic resources; TSVW, *Tomato spotted wilt virus.*

The stewards of our agricultural future conserve and sustainably use plant genetic resources (PGR), the organs and tissues (seeds, fruits, cuttings, pollen, tissue cultures, etc.) by which plants can be propagated. The original PGR stewards were, and in some cases still are, farmers, gardeners, families, and agricultural communities. At present, they also include institutions, organizations, networks, and governments. This paper focuses on those which I know best: the constituent genebanks and personnel of the USDA-ARS's National Plant Germplasm System (NPGS; Byrne et al., 2018), plus other US and international PGR genebanks with which I am familiar. The reader is directed to Nabhan (1989), Dworkin (2009), Nabhan (2009), Fu (2017), and Byrne et al. (2018) for more extensive coverage for several of the general PGR stewardship themes dealt with here. Also, Bretting and Duvick (1997) reviewed the topic of dynamic, in situ PGR stewardship some years ago, whereas Bellon et al. (2017) and Greene et al. (2014) provide valuable recent treatments for this subject.

The immediate burdens of contemporary PGR stewardship often rest on the shoulders of individuals: breeders, researchers,

Published in Crop Sci. 58:2233–2240 (2018).
doi: 10.2135/cropsci2018.05.0334

plant explorers, information technologists, curators, and PGR managers. They are as diverse a group of humanity as imaginable but, from my experience, they do share some traits in common—some admirable, some remarkable, and some exasperating. They are acquisitive accumulators who frequently stretch the boundaries of their and their institutions' operational and managerial capacities. Characteristically curious and inquisitive, they also must be innovative to successfully handle the unusual demands of PGR stewardship. By nature and by necessity, they are often generalists; the best are polymaths. Many are persistent—to the point of stubbornness—and are demanding perfectionists for whom enough is never good enough. The quest for perfection can be mistaken for elitism, but it actually reflects their intense commitments to fulfilling difficult missions.

Safeguarding PGR for posterity is a complicated, multicomponent process that requires comprehensive planning on an extended timescale. Activities that comprise PGR stewardship include, roughly in order of importance: PGR maintenance (discussed at greater length below), regeneration and increase, acquisition, documentation and data management, distribution, characterization, evaluation, and genetic enhancement (Fu, 2017). Some PGR stewards and their institutions conduct all these activities, whereas others focus only on a subset. Many PGR stewards and their collaborators also conduct research designed to improve the efficiency and effectiveness of PGR stewardship and to add value to the PGR conserved (Walters et al., 2008). For sustained success in stewardship, some sort of larger "stewardship community" is often key and should include PGR users (Widrlechner, 1997) such as the NPGS's Crop Germplasm Committees (CGC) and Technical Advisory Committees (TAC; GRIN-Global, 2017; Byrne et al., 2018). Like community or family members of a smallholder farmer's village (Brush, 2004; Bellon et al., 2015), members of those committees provide PGR stewards with invaluable support, encouragement, and, of course, critiques.

Plant genetic resource stewardship in genebanks involves not only scientific considerations. It also requires concerted actions among sometimes divergent institutions and individuals where human organizational and sociological factors come into play (Halewood et al., 2018). Although it might seem trite, trust and good will are instrumental for successful PGR stewardship irrespective of legal mechanisms such as formal treaties, memoranda of understanding, etc. Plant genetic resource stewardship can seem to advance maddeningly slowly, but trust and goodwill can accelerate progress to payoffs, which can be huge (see PGR Stewardship Successes and Challenges below).

The size, quality, and complexity of organizations and institutions that safeguard PGR are as varied as the PGR stewards themselves. Some of the so-called "base collections" for national genebank systems, such as those of Mexico (Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuaria, 2012), the Republic of Korea (Rural Development Administration-Genebank Information Center, 2015), and the United States (USDA-ARS, 2018a) operate from technically sophisticated facilities. But most genebanks occupy rather modest, unobtrusive quarters with surprisingly few staff considering the quantity of PGR managed and the complicated processes involved (e.g., see USDA-ARS, 2018b) Understated efficiency and low-key operations can sometimes contribute to underappreciation and lack of recognition (Dworkin, 2009; Geiling, 2016) for the institution's valuable contributions to PGR stewardship. From an institutional perspective, a vital element for safeguarding PGR diversity is diversity in sources of financial support (e.g., the long-term partnership between the US federal and state governments to support NPGS genebanks; Byrne et al., 2018), which can contribute to operational stability and continuity. But financial diversity can also result in administrative complications such as different fiscal years, spending regulations, etc., which produce operational inefficiencies.

Nonetheless, the performance and impact of these PGR stewardship institutions ultimately depend directly on the quality of their staffs and the institutions' capacity to enable their staffs to devote sustained, unimpeded effort over decades. For example, an NPGS curator seems to reach full stride after about a decade of experience (Widrlechner, 1997), and by the 30-yr mark—yes, many of them serve 30+ years—often their contributions have been extremely valuable.

PLANT GENETIC RESOURCE STEWARDSHIP SUCCESSES AND CHALLENGES

Fu's incisive analyses (Fu, 2017) of the challenges and vulnerabilities encountered by PGR genebanks deserve careful deliberation and discussion. Lest it be thought that those challenges are diagnostic of a largely dysfunctional international PGR genebank system, some recent PGR stewardship successes should also be noted and celebrated. For example, during the last 8 yr, the NPGS has distributed an average of 250,000 samples yr^{-1} (Fu, 2017) or a total of 2 million during that period. The individual research centers of the Consultative Group for International Agricultural Research (CGIAR) such as the International Rice Research Institute and the International Center for Maize and Wheat Improvement have also distributed many PGR samples. Just ponder all the different PGR stewardship operations—acquisition through distribution—that must synchronize and function effectively to deliver hundreds of millions of seeds and other propagules to end users around the world.

Decades ago, the storage capacities of some major genebank facilities (e.g., the NPGS's National

Laboratory for Genetic Resources Preservation [NLGRP] in Ft. Collins, CO) were inadequate. Thanks to the vision and tireless work of NLGRP staff, USDA administrators, and customer and stakeholder advocates, storage capacity in the NLGRP was increased substantially (Shands, 1995). The 2016 Meyer Medal Awardee Cary Fowler succeeded in transforming his vision for safeguarding the world's supply of PGR into the Svalbard Global Seed Vault (Fowler, 2016) thanks to support from Norway, the United States, the Global Crop Diversity Trust (GCDT), and other donors. Consequently, as compared with past decades, a substantially greater proportion of the world's PGR has now been successfully secured ex situ.

Sixty years ago, some NPGS genebanks relied on Royal McBee edge-notched paper cards (Wikipedia, 2018; M. Spinks, personal communication, 2017) to manage and analyze descriptive data associated with PGR. Today, the NPGS's PGR information management system, the Germplasm Resources Information Network (GRIN)-Global (Byrne et al., 2018), serves the needs of PGR stewards in nine different nations and is poised to become the international standard for PGR information management. A combination of incremental progress and periodically disruptive technological innovations (e.g., the personal computer and the World Wide Web; Halewood et al., 2018) has characterized the evolution of PGR information management systems such as GRIN-Global and Genesys, a website that aggregates information from GRIN-Global and other databases to facilitate PGR distribution (Genesys, 2018).

Historically, global stewardship of crop wild relatives (CWR) had not met critical conservation needs (Castañeda-Álvarez et al., 2016), but recently an international team of PGR stewards, with support from the GCDT, USDA, CGIAR, universities, and others, has begun to achieve substantial progress in setting global priorities for CWR stewardship (Castañeda-Álvarez et al., 2016). This planning has been pursued in the United States through international (Khoury et al., 2013) and interagency US federal government cooperation (e.g., USDA-ARS and US Department of Interior Bureau of Land Management, Haidet and Olwell, 2015; USDA Forest Service and USDA-ARS, 2014) that forms a foundation for conserving CWR in the United States and elsewhere (Walters, 2015; Castañeda-Álvarez et al., 2016).

Despite the preceding successes, PGR stewards face many challenges, some of which are long standing and seemingly intractable. More than 20 yr ago, the landscape plant conservationists Graudal et al. (1995) bemoaned that the "central dilemma of gene resource conservation is a recognized need for conservation without knowing exactly what to conserve" (p. 27). Alas, the preceding "dilemma" still prevails today. Although many more genetic and trait data are now available for PGR, detailed knowledge of local, regional, and global patterns of PGR diversity are often lacking (Fu, 2017). The foresight for predicting future agricultural needs for PGR, which Widrlechner (1997) years ago identified as essential, is still elusive.

Plant genetic resource stewardship increasingly has been complicated by diverse factors such as the national implementation of international PGR agreements, unwanted biological exchanges, and extreme weather. International treaties such as FAO's International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA; Esquinas-Alcázar, 2005) and the Convention on Biological Diversity (2018) have been established to contribute positively to PGR stewardship by furnishing an international framework for PGR access, conservation, and sustainable use and the equitable sharing of benefits generated by access to and use of PGR. They have stimulated the development and expansion of international PGR stewardship capacities and support mechanisms such as the GCDT and the ITPGRFA's Benefit-Sharing Fund (FAO, 2018). National governments, regional blocs, and international agricultural research centers have implemented new guidelines, requirements, and practices to implement those international agreements. Exchange of PGR consequently has become an increasingly formalized process. From a practical standpoint, PGR exchange now can involve arduous bureaucratic burdens (Halewood et al., 2018) for PGR stewards who already are struggling to meet increased demands for PGR and associated information without concomitant increases in the capacity to meet those demands (Gewin, 2017b).

The substantial increase in the volume of international trade and travel has exacerbated the risk of unwanted biological exchanges of introduced, invasive pests and pathogens. Those biological invaders can especially threaten field plantings of vegetatively propagated PGR that must be maintained as clones and PGR with seeds that cannot currently be safeguarded under standard long-term storage conditions (Walters et al., 2013). For example, the spread of the virulent laurel wilt pathogen (*Raffaelea lauricola* T. C. Harr. Fraedrich & Aghayeva) to the southeastern United States starting in 2002 has decimated wild laurels (species of the Lauraceae) and now threatens both the Florida avocado (*Persea americana* Mill., a member of the Lauraceae) industry and the NPGS avocado PGR collection in Miami, FL. In response, NPGS PGR stewards are conducting an expensive, time-consuming, multiyear program of establishing backup plantings for that collection in Hilo, HI (Gewin, 2017a). Those backup collections not only act as insurance against biotic threats but also against extreme weather such as devastating freezes, tornadoes, or hurricanes (McGrory, 2017).

"FLAW IN THE HUMAN CHARACTER"

Most PGR stewards and their institutions identify maintenance—keeping PGR alive, healthy, and safe—as the highest priority for stewardship. But ongoing support for PGR maintenance in genebanks has been largely insufficient (Duvick, 1984; Geiling, 2016; Fu, 2017), exemplifying the broader paradox highlighted by the author Kurt Vonnegut, Jr.: "Another flaw in the human character is that everybody wants to build and nobody wants to do maintenance" (Vonnegut, 1990). Notwithstanding this "flaw," securing the requisite support for PGR maintenance must be achieved to safeguard our agricultural future. But how?

First, the value to humanity of successful long-term maintenance of a wide spectrum of genetic diversity should be publicized. A peanut (*Arachis hypogaea* L.) sample from the NPGS constitutes one of the most striking examples of that value. PI 203396 was infrequently distributed and little used in research and breeding for 20+ yr after its incorporation into the NPGS during the 1950s. Decades later, it was found to be resistant to several virulent diseases, including *Tomato spotted wilt virus* (TSWV), which had become a serious threat to the US peanut industry in the late 1980s. PI 203396 was subsequently incorporated into the pedigrees of several peanut cultivars widely planted in the southeastern United States. By 2001, the economic value of that TSWV-resistance trait was estimated at US$200 million *per year* (Isleib et al., 2001). Today, the annual economic value of this one trait from one accession is likely a multiple of that amount, eclipsing the NPGS's entire 2017 annual budget ($44 million; Fu, 2017) for maintaining 580,000+ accessions of 15,700+ species.

Additional examples for the value of NPGS PGR include a sweet potato [*Ipomoea batatas* (L.) Lam.] accession that has contributed an effective source of resistance to fusarium wilt (*Fusarium oxysporum* f. sp. *batatas*), the most serious disease of sweet potato in the United States (Clark et al., 2013). Without that source of resistance, there would be no sweet potato industry in the United States (D. LaBonte, personal communication, 2018). An NPGS apple [*Malus Xrobusta* (Carrière) Rehder] rootstock accession is the source of host-plant resistance to fire blight [*Erwinia amylovora* (Burrill) Winslow et al.], the most serious disease of apples in the United States (Norelli et al., 2003) and worldwide. The annual positive impact of this resistance for US apple production is estimated conservatively at $100 million (Norelli et al., 2003; C.T. Chao and G. Fazio, personal communication, 2018). Miklas (personal communication, 2018) estimates the cumulative value to the US common bean (*Phaseolus vulgaris* L.) industry of disease resistance traits [e.g., resistance to common blight *Xanthomonas campestris* pv. *phaseoli* Smith (Dye); Singh and Miklas, 2015] derived from NPGS PGR accessions as conservatively $500 million+. Similar examples for the economic and societal values of maintaining a broad spectrum of PGR have been recounted (Qualset and Shands, 2005) for numerous other crops, both in the United States and globally. The cumulative annual impacts of the preceding and other NPGS accessions, CGIAR genebank accessions, etc., are not only enormous monetarily, but also immense in terms of human hunger and misery mitigated.

Second, it must be widely recognized that failing to incorporate PGR into genebanks or to maintain PGR and associated information adequately can diminish the productive potential of US and global agriculture and increase its susceptibility to threats (Qualset and Shands, 2005; Byrne et al., 2018). Loss of PGR can occur from catastrophic events such as the challenges mentioned above plus others such as fires, warfare, etc. (Gewin, 2015; Fu, 2017). Deterioration of PGR quality in genebanks can progress gradually and insidiously as PGR in orchards or cold storage lose identities, vigor, and viability from neglect or inadequate capacity to rejuvenate and maintain them properly (Gewin, 2015; Fu, 2017). Estimating quantitatively the direct effects on US and global agriculture from inaccessible or inadequately maintained PGR is problematic. Nonetheless, historical information can illustrate such impacts at least qualitatively for particular cases. For example, starting almost a hundred years ago, multiple ex situ PGR collections for guayule (*Parthenium argentatum* A. Gray), the strategically important source of natural rubber, were assembled and maintained serially by USDA, universities, arboreta, and rubber company research programs. Because of periodic funding lapses, shifting institutional priorities, and economic factors, much of the original PGR and/or accompanying key descriptive information were lost from those collections. Consequently, additional plant explorations had to be conducted and ex situ collections had to be renovated—at substantial costs of time and money—to try to safeguard and deliver the genetic raw material requisite for breeding this still nascent industrial crop (Ilut et al., 2015, 2017).

Third, the moral and civic responsibilities for maintaining and making PGR available to humanity now and in the future must be fulfilled. Numerous faiths and cultures have revered and honored "seed keepers" and their work, as documented by sacred scriptures and historical texts. The "gardener President" Thomas Jefferson placed a high priority on PGR stewardship for the young US Republic (Jefferson, 1800). President Abraham Lincoln's administration and the 37th Congress established the USDA in 1862 "…to procure, propagate, and distribute among the people new and valuable seeds and plants" (37th Congress of the United States, 1862, p. 387). Subsequent administrations and Congresses have continued to support to variable degrees the USDA's capacity for PGR maintenance (Griesbach, 2013) on behalf of the American people and the global community. Internationally, public and private organizations, institutions, and nations—large and small—have also addressed these obligations especially through support of the GCDT, the CGIAR genebanks (CGIAR, 2017), and as Parties to the ITPGRFA. But much more remains to be done.

PLANT GENETIC RESOURCE STEWARDSHIP AND THE FUTURE

Plant genetic resource stewards have often relied on mixtures of new and age-old types of equipment and devices to manage PGR and key associated information. These "mixed technologies" are needed to handle the remarkable diversity in PGR propagule size, shape, weight, and physiological behavior (Widrlechner, 1997). For instance, NPGS curators combine simple "off-the-shelf" equipment such as glass jars and foil packets with barcoded labels and barcode readers to store PGR and communicate seed counts to sophisticated online inventory records, resulting in substantial gains in PGR managerial efficiency. Similarly, systems of environmental sensors and digital cameras have helped safeguard PGR field plantings. Such systems can generate substantial datasets that are intrinsically valuable but collectively might prove far more beneficial. That was the case for individual large ecogeographical, climatological, and PGR occurrence datasets which, when combined and analyzed, have yielded valuable insights for guiding and setting priorities for CWR conservation (e.g., Ramírez-Villegas et al., 2010; Sánchez González et al., 2018). The currently vast amount of information associated with PGR will grow ever more voluminous in the future (Halewood et al., 2018) and in turn increase the value of the PGR (Day Rubenstein et al., 2006). Plant genetic resource stewardship will likely increasingly become an information generation, quality assurance, and management effort, extending a long-term trend (Fu, 2017; Byrne et al., 2018).

Remarkable efficiency gains for PGR stewardship might result if and when the preceding types of digital data can interface with artificial intelligence (AI) applications. Today, AI underpins numerous applications (e.g., Alexa, Cortana, Siri, and Watson) available through the billions of "smart phones," "smart speakers," and other devices that are powerful, networked mobile computers (Khoso and Khan, 2016). Might future AI applications for PGR management autonomously answer simple queries from users (e.g., "do accessions *X* and *Y* have the same fruit shape, size, and color?"), or complicated queries regarding the optimal design of PGR collections or research projects (e.g., "which are the best accessions for ascertaining the range of adaptation for crop *Y*?")? The requisite search engines and algorithms clearly exist already in the commercial applications listed above, although currently they are often proprietary. In the future, powerful general AI applications will likely enter the public domain and become accessible for PGR management.

To function effectively, such AI applications require accurate and well-populated databases from which to draw information to meet the needs of specific analyses. Whenever possible, standardized data collection procedures must be adopted to improve data accuracy and to enable datasets from individual databases to be combined or interoperated readily. Despite the recent development of GRIN-Global and Genesys, such PGR databases are still in their infancy. They also require integration and harmonization with genome databases (e.g., through the DivSeek Initiative; DivSeek, 2018). Future PGR stewards might devote increasingly more of their time to maintaining and enhancing information management systems to enable successful functioning of custom-designed AI applications. Artificial intelligence applications and PGR information management overall also require advanced telecommunication network capacities. Those capacities could enhance the effectiveness of current PGR stewardship networks through more sophisticated webinars, videoconferences, and chatrooms that can foster online PGR stewardship communities.

Plant genetic resource stewardship networks are not a new idea (Widrlechner, 1997). They have been especially prevalent in Europe, with diverse outcomes (e.g., the European Cooperative Programme for Plant Genetic Resources; Maggioni and Engels, 2014). More than 25 yr ago, networks of the Instituto Interamericano de Cooperacíon para la Agricultura (IICA; Ramírez, 2008) evolved as a means for strengthening PGR stewardship in the Americas. For example, the IICA Cooperative Program in Agricultural Research and Technology for the Northern Region (PROCINORTE) network of Canada, Mexico, and the United States formed a genetic resources taskforce termed NORGEN, which has effectively fostered operational cooperation among the national genetic resource efforts of those nations (PROCINORTE, 2018). The NPGS itself has been a coordinated national PGR stewardship network for 40+ yr (Byrne et al., 2018); the CGIAR genebanks have been organizing similarly (CGIAR, 2017), and the DivSeek Initiative has been striving to form data integration and exchange networks (DivSeek, 2018).

The preceding developments conform to a broader global trend of expanding networks: "The world is now networked, and networks routinely beat hierarchies." (Hayden, 2017, p. 61). Emerging wider "social networks" for PGR stewardship are encompassing formal institutions and informal "interest groups" with governmental, nongovernmental, and private-sector elements. Diverse nongovernmental organizations—among others, seed savers, chefs, restaurateurs, community activists, Native American groups, philanthropists, specialty crop growers, and consumers—have assembled into extraordinary networks dedicated to diversifying the US food supply by conserving and encouraging the use of heirloom or heritage crop varieties in local food production (e.g., Nabhan, 2013). Notably, the Fine Chocolate Industry Association formed the Heirloom Cacao Preservation Fund as a means for creating a network with USDA-ARS and other partners to identify and conserve, both ex situ and in situ, heirloom varieties of fine flavor cacao (*Theobroma cacao* L.) vital to the profitability of on-farm cacao PGR stewards and producers (often traditional farmers), consumers, and the fine flavor chocolate industry (Heirloom Cacao Preservation Fund, 2018).

Innovative networks of PGR stewards and users, often catalyzed by a well-developed "online presence," have stimulated and likely will continue to stimulate innovation in PGR stewardship and sustainable use not only locally and regionally, but also potentially nationally and internationally. Technological innovations (Halewood et al., 2018) might magnify the impact of such networks. User-friendly online applications implemented on cell phones, such as those enabling farmers in Africa to diagnose and report the occurrences of cassava (*Manihot esculenta* Crantz) diseases and pests (Ramcharan et al., 2017), might be integrated with extensive ecogeographical, climatic, distribution, genotypic, and phenotypic datasets (e.g., Ramírez-Villegas et al., 2010; Sánchez González et al., 2018). That software integration could enable professionals, local communities, and interested individuals to monitor and report essentially in "real time" the conservation status and vulnerabilities for key PGR.

Considering the broader impacts of information technology, potentially revolutionary changes in US and global food chains might already be occurring as commercial organizations with massive information-powered logistical networks enter the realm of food marketing and delivery (Wingfield and de la Merced, 2017). The potential effects of such developments on producer, processor, and marketer profits, consumer food prices, and other factors are uncertain and subject to vigorous debate (Wingfield and de la Merced, 2017). The potential effects on PGR conservation and utilization apparently have not been considered as widely. Could easier access to online information about the great diversity of different cultivars and food types, combined with affordable prices, front door delivery, or convenient pickup at nearby sites, heighten demand for culinary diversity that consequently generates greater demand for PGR? Such demands could further strain the capacities of genebanks but also possibly offer unanticipated avenues for supporting PGR stewardship.

Lastly, human demographic trends constitute a tangible, not speculative, future challenge for PGR stewardship. Many PGR stewardship organizations in the United States and other nations, be they governmental (e.g., the NPGS), academic, private, or nongovernmental (e.g., Native Seeds/SEARCH, 2015), are experiencing or soon will experience the challenge of transferring knowledge, experience, practices, "lore," and skills to the next generation of PGR stewards. Advanced planning for future personnel staffing and formal training for potential leaders and inexperienced stewards will be crucial for maintaining the continuity of PGR stewardship.

A pioneer of computer programming, Admiral Grace Hopper, advised wisely that "Our young people are the future. We must provide for them. We must give them the positive leadership they're looking for…You manage things; you lead people" (Naval History and Heritage Command, Communication and Outreach Division, 2014, p. 4). Experienced PGR stewards must not only successfully manage PGR, the green line that stands between humanity and calamity, but also serve as *leaders* to mentor those who recently became or will soon become the PGR stewards of our agricultural future. It is a collective responsibility for all of us, regardless of our job title, career stage, or intrinsic talents, to provide such leadership and thereby begin to erase that "flaw in the human character" (Vonnegut, 1990).

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgments

This paper was adapted from a lecture delivered on the occasion of receiving the Frank Meyer Medal for Plant Genetic Resources on 24 Oct. 2017. I thank the Frank Meyer Medal for Plant Genetic Resources Committee for conferring this distinct honor. I thank Editor M. Warburton for inviting me to write this paper; C.T. Chao, G. Fazio, M.A. Gore, C.C. Holbrook, D. LaBonte, T. Porch, J.S.C. Smith, M. Spinks, G. Volk, M.P. Widrlechner, and K. Williams for providing literature references; and M.A. Gore, M.P. Widrlechner, and K. Williams for their valuable comments and edits to earlier versions of the manuscript.

Gratitude is extended to the past, current, and future PGR stewards, such as those in the NPGS, for safeguarding the world's agricultural future. The people of the United States are gratefully acknowledged for their steadfast support of the NPGS through appropriated federal funding to the USDA-ARS and USDA National Institute for Food and Agriculture (NIFA), appropriated state funding for state and land-grant universities and state agricultural experiment stations, and through crop commodity organizations. The advocacy and support of the US seed industry—especially through the American Seed Trade Association—for the NPGS, the CGIAR genebanks, the GCDT, and the ITPGRFA require special recognition and thanks. The GCDT's international leadership in PGR stewardship and support for developing GRIN-Global are gratefully acknowledged.

This paper is dedicated to the late Dr. Donald N. Duvick, whose wise counsel and career-long dedication to PGR conservation and sustainable use have inspired many and have significantly advanced global PGR stewardship for our agricultural future.

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