

Access to crop digital information and the sharing of benefits derived from its use: Background and perspectives

During the 900-day siege of Leningrad from 1942 to 1944, eleven staff members of the Soviet genebank for crop plants and their wild relatives, the All-Union Institute of Plant Industry (now known as the N.I. Vavilov Institute for Plant Genetic Resources or the VIR, after its most famous leader), starved to death protecting its invaluable holdings (Alexanyan & Krivchenko, 1991; Loskutov, 1999). These researchers gave their lives to preserve diversity in crops—from wheat to potatoes, apples to flax—as well as all the information that the scientists had learned about them over the years. They understood the critical importance of the seeds, tubers, and buds, and also the data about their useful characteristics, to the future development of the Soviet State and to global agriculture. They hoped that the coming generations would be able to access these biological materials and associated information, and thus share in the benefits derived from their use.

Three quarters of a century later, crop diversity remains as valuable to global food security as ever. Yet the information about this diversity seems to have become nearly as important as the seeds themselves. With the advent of high-throughput DNA sequencing technologies and emerging “phenomic” approaches, and new platforms to store and explore the data they generate, the ways in which our global community can produce and access this information, and share the benefits of its use, is rapidly changing, creating a set of challenges that we will explore in a special collection of papers in *Plants, People, Planet*.

N.I. Vavilov had a vision for the potential of crop diversity to improve agricultural production. After devastating famines experienced in 1919–1921—caused by poor weather and farm collectivization—restoring farm productivity was essential in the Soviet Union. The genetic resource collections compiled between the two World Wars by Vavilov and his colleagues included crop traits such as early maturity, cold hardiness, and disease resistance. These invaluable resources enabled the expansion of cereal, legume, oilseed, fiber, timber, fruit, and vegetable crops over much broader areas of the Soviet Union than previously possible (Dzyubenko, 2018).

Similar trends were happening around the world (e.g., Reitz & Salmon, 1968; Salvi, Porfiri, & Ceccarelli, 2013). During and following the Second World War, Norman Borlaug, the Green Revolution pioneer, was able to mobilize crop diversity to develop dwarf stature, disease resistance, and absence of seasonal cues to breed higher

yielding wheats in Mexico (Borlaug, 2002, 2007; Swaminathan, 2009) while M.S. Swaminathan and other colleagues adapted these techniques and technologies for expansion into India and beyond (e.g., Swaminathan, 2006).

Today's genebanks are essential to maintaining the resilience of the global agricultural system in the face of climate change, new pests and diseases, shifts in trade and dietary preferences, natural resource limitations, and armed conflicts (Figure 1). The recent loss of access to the International Center for Agricultural Research in the Dry Areas (ICARDA) genebank collections in Aleppo, Syria, in the midst of the Syrian civil war—accessions which were thankfully duplicated at sister international genebanks and at the Svalbard Global Seed Vault—demonstrates the need for continued international collaborations to safeguard these resources for the long-term.

These *ex situ* conservation systems can only fulfill their full intended roles if researchers, educators, plant breeders, and ultimately farmers and the consumers of their produce have access to these resources. Furthermore, access is increasingly dependent on equitable sharing of the benefits derived from the use of crop diversity with their custodians.

The seeds held by the VIR during the Second World War, as well as those in similar genebanks in other industrialized nations, were initially collected from farms and marketplaces without officially mandated benefit to the communities from whom they were originally gathered. Many of the approximately 325,000 accessions collected by Vavilov and his colleagues were obtained from areas then ruled as colonies of European nations. Even after independence came to these areas after the War, further collections built by national genebanks and the international system such as the Consultative Group for International Agricultural Research (CGIAR) through the early 1990s were generally made without globally coordinated agreements regarding benefit sharing.

Since the Convention on Biological Diversity (CBD) was established in 1992, the international community has enacted legally binding arrangements to provide access to and share benefits derived from the use of crop diversity. Through the 2004 International Treaty on Plant Genetic Resources (ITPGRFA), which is aligned with the CBD, and the CBD's own 2010 Nagoya Protocol, mechanisms for access and benefit sharing (ABS) of seeds and other reproductive propagules have been more carefully formalized.

 This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2020 The Authors, *Plants, People, Planet* © New Phytologist Trust



FIGURE 1 Samples of beans conserved in the international collections of the International Center for Tropical Agriculture (CIAT) genebank in Colombia. Photo by CIAT/ Neil Palmer



FIGURE 2 Aeroponic phenotypic characterization of cassava at the International Center for Tropical Agriculture (CIAT), Colombia. Photo by CIAT/ Neil Palmer

With the advent of increasingly powerful information-generating technologies applicable to the exploration of plant genetic resources, including DNA sequencing, gene editing, genomic selection, and high-throughput phenomic characterization, our capacity to understand potentially useful variation and to incorporate it into cultivars has grown (e.g., Arora & Narula, 2017; Crossa et al., 2017;

Mir, Reynolds, Pinto, Khan, & Bhat, 2019) (Figure 2). Because these technologies are potentially so transformative, the information they generate has been proposed to be included as part of international access and benefit sharing mechanisms (e.g., Aubry, 2019). As an extreme case, one could imagine that these “game changing” technologies may make crop improvement programs less reliant on the actual biological propagules, that is, the seeds, tubers, and buds, in turn lessening the benefits achieved through mechanisms covering exchange of these physical resources.

International debates around including genetic sequence and phenotypic information in the ABS mechanisms of the Nagoya Protocol and the ITPGRFA could have significant impacts on the international flow of information relevant to plant breeding and the conservation of crop genetic resources. Many of these data are currently held in open access formats (Laird et al., 2020). International negotiations on access and benefit sharing of such data have the potential to create increased benefit sharing deriving from their use, but also may hinder important research and dissemination of results.

These issues are complex. We believe that creating a forum to highlight the science underlying these technologies and to encourage discussions based on a range of informed opinions on access and benefits surrounding these tools, will make for more productive debates. Ultimately, we hope for international agreements that are effective in their encouragement of equitable sharing of the benefits



of plant genetic resources essential to maintaining the productivity, resilience, and nutritional quality of culturally desirable food, fiber, and fuel, in the face of climate change. And from this, there should arise a more accessible global system of conservation and use of crop diversity and associated information, for the benefit of all.

We are creating a special collection of *Plants, People, Planet* to provide a space for this range of opinions as well as examples and background information on these complex and challenging topics. Our issue seeks submissions for several distinct types of articles to further these essential conversations:

- Perspectives and Opinions on genomic and phenomic data and access and benefit sharing that balance not just expertise, but institutional affiliation and geography. Our aim is to facilitate the expression of a broad range of considered opinions, without bias towards particular regions, institution types, or other aspects of background.
- Technical Reviews on the current state-of-the-art for a variety of new technologies that are central to debates about genetic and phenotypic information on plant genetic resources, including gene editing, genomic selection, high-throughput phenomics, and pertinent information systems. Of particular interest would be articles that discuss the application of these technologies for crop development, and related issues with regard to ABS.
- Historical perspectives, such as those on past agreements, on previous collections, and on the essential roles of particular institutions, such as botanic gardens and CGIAR centers in crop improvement and the implementation of access and benefit sharing.
- Case studies on plant genetic resources and genetic or phenomic data for particular crops. Ideally, these should reflect more than one dimension, e.g., data collection, storage, access and use, value extraction, possible and actual commercial applications, and benefit sharing.

KEYWORDS

digital sequence information, food security, genomics, phenomics, plant genetic resources

Eric von Wettberg¹ 
Colin K. Khoury^{2,3} 

¹Department of Plant and Soil Sciences and Gund Institute for the Environment, University of Vermont, Burlington, VT, USA

²International Center for Tropical Agriculture (CIAT), Cali, Colombia

³Department of Biology, Saint Louis University, St. Louis, MO, USA

Correspondence

Eric von Wettberg, Department of Plant and Soil Sciences and Gund Institute for the Environment, University of Vermont, Burlington, VT 05405, USA.

Email: Eric.Bishop-von-Wettberg@uvm.edu, C.Khoury@cgiar.org

ORCID

Eric von Wettberg  <https://orcid.org/0000-0002-2724-0317>

Colin K. Khoury  <https://orcid.org/0000-0001-7893-5744>

REFERENCES

- Alexanyan, S. M., & Krivchenko, V. I. (1991). Vavilov Institute scientists heroically preserve world plant genetic resources collections during World War II siege of Leningrad. *Diversity*, 7(4), 10–13.
- Arora, L., & Narula, A. (2017). Gene editing and crop improvement using CRISPR-Cas9 system. *Frontiers in Plant Science*, 8, 1932. <https://doi.org/10.3389/fpls.2017.01932>
- Aubry, S. (2019). The future of digital sequence information for plant genetic resources for food and agriculture. *Frontiers in Plant Science*, 10, 1046. <https://doi.org/10.3389/fpls.2019.01046>
- Borlaug, N. E. (2002). *The green revolution revisited and the road ahead*. Stockholm, Sweden: Nobelprize.org.
- Borlaug, N. E. (2007). Sixty-two years of fighting hunger: Personal recollections. *Euphytica*, 157(3), 287–297. <https://doi.org/10.1007/s10668-1-007-9480-9>
- Crossa, J., Pérez-Rodríguez, P., Cuevas, J., Montesinos-López, O., Jarquín, D., de los Campos, G., ... Varshney, R. K. (2017). Genomic selection in plant breeding: Methods, models, and perspectives. *Trends in Plant Science*, 22(11), 961–975. <https://doi.org/10.1016/j.tplants.2017.08.011>
- Dzyubenko, N. I. (2018). Vavilov's collection of worldwide crop genetic resources in the 21st century. *Biopreservation and Biobanking*, 16(5), 377–383. <https://doi.org/10.1089/bio.2018.0045>
- Laird, S., Wynberg, R., Rourke, M., Humphries, F., Muller, M. R., & Lawson, C. (2020). Rethink the expansion of access and benefit sharing. *Science*, 367, 1200–1202. <https://doi.org/10.1126/science.aba9609>
- Loskutov, I. (1999). *Vavilov and his institute, a history of the world collection of plant genetic resources in Russia*. Rome: IPGRI.
- Mir, R. R., Reynolds, M., Pinto, F., Khan, M. A., & Bhat, M. A. (2019). High-throughput phenotyping for crop improvement in the genomics era. *Plant Science*, 282, 60–72. <https://doi.org/10.1016/j.plantsci.2019.01.007>
- Reitz, L. P., & Salmon, S. C. (1968). Origin, history, and use of Norin 10 Wheat 1. *Crop Science*, 8(6), 686–689. <https://doi.org/10.2135/crops.ci1968.0011183X000800060014x>
- Salvi, S., Porfiri, O., & Ceccarelli, S. (2013). Nazareno Strampelli, the 'Prophet' of the green revolution. *The Journal of Agricultural Science*, 151(1), 1–5. <https://doi.org/10.1017/S0021859612000214>
- Swaminathan, M. S. (2006). An evergreen revolution. *Crop Science*, 46(5), 2293–2303.
- Swaminathan, M. S. (2009). Norman E. Borlaug (1914–2009). *Nature*, 461(7266), 894–894.