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OPINION & POLICY

Training in Plant Genetic Resources Management: A Way Forward

Gayle M. Volk, Deana Namuth-Covert, and Patrick F. Byrne*

ABSTRACT

Plant genetic resource collections are national treasures that are critical to the success of breeding programs and the long-term resiliency of agriculture in the United States and worldwide. The USDA National Plant Germplasm System (NPGS) is a coordinated network of 19 genebank locations throughout the United States that conserve and protect nearly 600,000 accessions representing ~16,000 plant species. The expertise of current curators must be captured, and training materials must be developed to educate the next generation of those who maintain and use plant genetic resources. A group of experts convened in April 2018 to discuss the needs, pedagogical approaches, educational content, delivery platforms, and mechanisms for sustaining a possible future plant genetic resources management training program. A three-component approach was envisioned to achieve the task of educating current and future genebank managers, as well as those who use genetic resources in their research and breeding programs. The proposed training program will include the development of online Resource Libraries, online courses, and workshops. Resource Libraries, hosted by GRIN-Global, will make learning objects, downloadable information, and links to other online sources publicly available. These Resource Libraries will be available for use in existing classes, as well as for the development of new workshops and online courses. Development of, and public access to, training resources will capture key information about genebanking, make it more widely available, and secure its long-term viability.

G.M. Volk, USDA-ARS National Lab. for Genetic Resources Preservation, 1111 S. Mason St., Fort Collins, CO 80521; D. Namuth-Covert, College of Food, Agricultural, and Environmental Sciences, The Ohio State Univ., Columbus, OH 43210; P.F. Byrne, Dep. of Soil and Crop Sciences, 1170 Campus Delivery, Colorado State Univ., Fort Collins, CO 80523. Received 20 Nov. 2018. Accepted 23 Jan. 2019. *Corresponding author (patrick.byrne@colostate.edu). Assigned to Associate Editor Ali Missaoui.

Abbreviations: NGO, nongovernmental organization; NIFA, National Institute of Food and Agriculture; NPGS, National Plant Germplasm System.

The USDA-ARS National Plant Germplasm System (NPGS) is a coordinated network of 19 genebank locations throughout the United States that perform research to acquire, maintain, regenerate, document, distribute, characterize, and evaluate plant genetic resources that, through breeding and selection programs, underpin crop improvement and agricultural production (Byrne et al., 2018). The NPGS currently maintains 596,000+ accessions representing 15,900+ species (USDA, 2018). It is also one of the world's largest distributors of plant genebank materials, distributing 279,000 accessions in 2017, with approximately one-third of those accessions provided to the international community.

A US-based training program for plant genetic resources management is clearly needed to benefit future genebank managers as well as plant breeders and other scientists who use plant genebank collections. An estimated 30% of the staff members of the NPGS are, or will be, eligible to retire over the next 5 yr. At present, the NPGS has no encompassing strategy to train replacements, yet there is a tremendous need to maintain the programmatic continuity and requisite skills to conserve collections of plant germplasm that include everything from elite and heritage cultivars to weedy and wild relatives of crops important

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to American and international agriculture. Crop curators have acquired the requisite skills for maintaining vast collections of plant genetic resources through many years of specialized training and on-the-job experience, thus ensuring that US national plant collections maintain their genetic integrity and viability indefinitely. United States and international genebanks seek to hire new scientific and technical staff with skills in agronomy, horticulture, genetics and genomics, plant ecology, phenotypic evaluations, and bioinformatics to apply the most up-to-date technologies in their collections, but only a few students are being trained at any one university. Ongoing professional development trainings are equally sparse.

A National Institute of Food and Agriculture (NIFA) planning conference grant supported a workshop for a group of experts to discuss this topic at the USDA-ARS National Laboratory for Genetic Resources Preservation in Fort Collins, CO, from 24 to 26 April 2018 to begin to address this critical need. The 31 experts represented USDA-ARS (11 participants), USDA-NIFA (3), land-grant universities (12), the seed industry (1), the national genebanks of Mexico and Canada (2), a botanic garden (1), and an international nongovernmental organization (NGO) for plant genetic resources conservation (1). This group discussed the needs, pedagogical approaches, educational content, delivery platforms, and mechanisms for sustaining a possible future plant genetic resources management training program. The objective of this paper is to describe the outcomes of this workshop, including the target audience, program goals, content, delivery, and components for the proposed plant genetic resources management training program.

FRAMEWORK FOR A PLANT GENETIC RESOURCES MANAGEMENT TRAINING PROGRAM

Audience

A training program for plant genetic resources management could benefit multiple audiences: academia, genebank managers and technicians, members of the public, NGOs, and for-profit companies, as well as public gardens and others that are passionate about plant diversity, seed saving, and food production. It will be of particular interest to undergraduate students with enthusiasm for food security, conservation of natural resources, plant genetic diversity, breeding, agronomy and horticulture, and biotechnology applications. A training program would also be of value to US and international graduate students and established scientists in both the public and private sectors with a basic or advanced understanding of the plant sciences. Clearly, these diverse audiences would have a wide range of background knowledge and expertise. Our initial foray into developing a plant genetic resources training program will focus on a selected audience, with the possibility of extending the program more broadly in the future. Initially, training materials will be developed to target an upper-level undergraduate and graduate student audience with a basic background in plant science, plant breeding, genetics, and/or plant propagation. The program will be modular to provide both general training in core concepts and higher level training in specialized topic areas to meet the needs of professional development audiences that may not be seeking academic credentials.

Program Goals

The group that convened in April 2018 identified the following goals for the plant genetic resources training program:

1. To build and sustain the human capacity to appreciate, maintain, and promote utilization of plant genetic resources.

2. To educate professionals in principles and practices of genetic resources management, utilization, and conservation.

Program Content

A core component of the training program will be focused on genebank operations, including key skills and issues about which genebank employees need to be knowledgeable. These include plant genetic diversity, population genetics, plant and seed physiology, germplasm utilization for research and breeding, regulatory issues, and methods for phenotyping, genotyping, and envirotyping (characterizing an environment based on factors affecting plant growth; Xu, 2016). In addition, professional skills in communication, writing, leadership, and the development of standard operating procedures should be considered. In some cases, training programs and materials are already available for some aspects of plant genetic resources management, either within the United States or internationally, such as through the "Crop Genebank Knowledge Base" (https://cropgenebank.sgrp.cgiar.org/). The relevance of existing programs to the needs of the genebanking community must be evaluated, and information about those programs should be made publicly available. In addition, feedback on the content, quality, and availability of materials will be sought.

Program Delivery

A genetic resources management training program must capture key knowledge and package it in a compelling and accessible format. Program delivery must be done in a manner that is financially sustainable. The development of a training program may have some central organizers but will also require a distributed network of experts with expertise in specific genebank-related subject areas, technology delivery tools, and teaching skills for successful

program execution. It will consider international perspectives and a variety of teaching and learning mechanisms (such as hands-on workshops, webinars, online classes, and individual training and mentoring), which will likely not be centered on traditional classroom lectures. The program must also remain current, with the capacity to be reviewed and updated as necessary. Training systems that include mentoring and hands-on training will remain relevant and crucial to the successful training of current and future genebank managers. In addition, a Training Oversight Committee will be established to guide and direct training activity efforts.

Program Components

The envisioned plant genetic resources training program will have three complementary elements (Fig. 1):

- Publicly available Resource Libraries for learning objects, downloadable information, and links to other online sources. The Resource Libraries could be hosted by GRIN-Global (similar to https://www.ars-grin.gov/npgs/gringlobal/webpages/publicwebsite.html) or other shared platforms. The "learning objects" are packaged presentations (course lessons, video, animations, and digital resources) with content that addresses a specific learning objective and take a learner approximately 5 to 15 min to complete. Learning objects can stand alone or can be incorporated into other educational content. The downloadable information in the Resource Libraries might include best practices, standard operating procedures (SOPs), regulations, case studies, handbooks, images, and/or popular press articles. In addition, links to other online resources, including training opportunities within the United States and abroad, will be provided. All content in the Resource Libraries would be peer reviewed for accuracy and instructional quality before posting. Such publicly available Resource Libraries developed by content-matter experts and educational specialists will capture key expertise and enable flexibility for content use and updating as necessary. The Resource Libraries provide the benefit of being freely available at any time and can be updated as needed. A drawback is that an instructor is not readily available to guide the learning process and answer questions.

- Online courses will be made available for either academic credit or noncredit continuing education. Online learning options have the potential to reach a wide audience yet still provide personalized instruction and networking opportunities. These

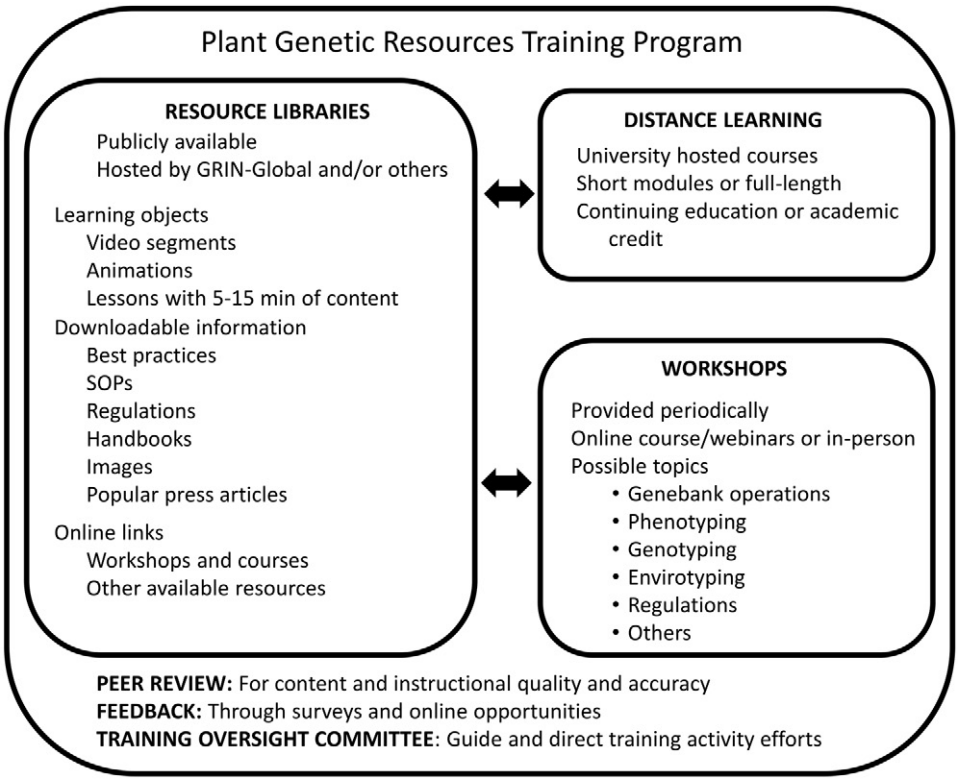

Fig. 1. Diagram of the components of the proposed plant genetic resources training program that will include (i) Resource Libraries, (ii) distance learning, and (iii) workshops. The training program will incorporate peer review to ensure that high-quality materials are provided, feedback from the user community, and an oversight committee to guide and direct training activity efforts. The abbreviation "SOPs" in the figure refers to standard operating procedures.

opportunities will likely be hosted by a consortium of universities and will be sustained through tuition and fees. They will be instructor-led training of either shorter, one-credit modules and/or full quarter- or semester-length courses. They may also be associated with a certification or accreditation process that would document educational achievement. An online learning multi-institution collaboration may reduce education and training material development costs, lower administrative barriers such as registration, and reach wider audiences, thereby increasing program cost effectiveness. This approach, although valuable, will require strong support and commitment from the host institutions (e.g., for transfer of credits) if it is to function smoothly.

- Periodic face-to-face workshops or in-person or online lectures and discussion groups will provide detailed training on specific methods or issues relevant to plant genetic resources management. Subject areas could include, but are not limited to, phenotyping, genotyping, envirotyping, pre-breeding, data management, intellectual property and regulatory issues, and the operations of specific genebank components (field genebanks, pathology, regeneration, seed and clonal conservation, etc.). These subject-specific workshops will provide opportunities for interested individuals to acquire in-depth knowledge in areas where the technology may be actively changing or where hands-on practice and experiences are needed. Training fees would likely be charged for cost recovery to develop and deliver such events. These efforts will be focused on specific needs in the genebanking community and will not necessarily provide an overall perspective.

Development of Learning Resources

High-quality learning objects underpin the development of both online and face-to-face education and training. The small, stand-alone educational learning objects can be repackaged and repurposed. They represent the foundation of online learning and are most used when organized in an online repository (Cohen and Nycz, 2006), thus increasing the impact of the learning objects after the initial time and financial resource investments have been made. Public availability also facilitates collaborations among content experts, instructors, and learners.

End users will have different overall goals and learning approaches, and these must be considered when developing educational materials and opportunities. For example, an academic student's goal may be to earn a high grade that ultimately leads to a degree, and therefore, such a student would be motivated to earn an acceptable score on a learning object quiz. However, a noncredit learner already established in a career may not have the need to complete an entire course but instead may be seeking more specific knowledge to assist them on the job. For this person, a quiz score is not as relevant as deeply comprehending the presented material that addresses a challenge they need to solve in their career or workplace. In this context, instructors must consider their diverse audiences when defining "success" and (re)package learning objects in such a way to accommodate each learner type (Nugent et al., 2018).

Learning objects have been successfully implemented in online agronomy education programs. For example, the online web lesson and learning object "Perennial Grass Growth and Development" is available in the Plant and Soil Sciences eLibrary at http://passel.unl.edu/communities/index.php?idinformationmodule=1130447263&idcollectionmodule=1130274200. This learning object was peer reviewed and published by the journal *Natural Sciences Education* (Guretzky et al., 2014). The online lesson is freely available for public and educational use, and it has been used in both introductory and advanced undergraduate courses (Nugent et al., 2016).

The training network described here will be valuable in its own right and could also serve as a model for the development of specialized educational resources on other topics that draw on a wide range of geographically distributed expertise.

CONCLUSIONS

A plan must be developed and implemented to provide a strong workforce pipeline for the next generation of those who will manage and utilize plant genetic resources. The vast scientific knowledge, expertise, and experience available within the NPGS and other communities must be captured before key personnel retire. The development of online Resource Libraries, online learning opportunities, and workshops will help to fill this need. The task is daunting and long overdue; however, the planned approach of creating learning objects will provide a mechanism to spread the workload and investment among many developers. Placing these objects into a repository at GRIN-Global will foster ongoing educational collaborations and encourage a broad use of the materials. Such long-term Resource Libraries will host various learning objects, course content, key documents, etc., that can be used stand alone or as part of instructor-led training opportunities both nationally and internationally. Just as it is understood that our genebanks must have well-maintained, high-quality genetic resources, it is equally important to maintain and share the knowledge of how to manage these priceless collections.

Conflict of Interest

The authors declare that there is no conflict of interest.

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