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RESEARCH

Survey Identifies Essential Plant Genetic Resources Training Program Components

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ABSTRACT

High-quality plant collections are maintained by personnel with specialized skills, based on a foundation of expertise in numerous fields. The lack of formal training opportunities in plant genetic resource management, both in the United States and globally, represents a challenge to plant genebanks whenever new personnel are hired. An English-language survey was developed and distributed to representatives of the worldwide plant genetic resources community to assess the needs for specific topics and preferred delivery methods of training materials. A total of 425 survey responses were received that were suitable for detailed analyses. Survey respondents included those from academia (higher education), the US National Plant Germplasm System (NPGS), Consultative Group for International Agricultural Research (CGIAR) genebanks, government genebanks (non-NPGS-affiliated), nongovernmental organizations, and the private sector. Survey respondents agreed that there is a shortage of high-quality learning materials on plant genetic resources, and that learning materials would be useful for researchers in their current positions, would advance careers, and would be useful in teaching or providing information to others. Training topics of high priority to the respondents include crop wild relatives, phenotyping, genotyping, and associated information. In addition, plant genetic diversity, germplasm preservation, gap analyses, prebreeding, and intellectual property are of interest. The proposed training materials must be designed to benefit multiple audiences, especially currently employed personnel and graduate students, postdocs, and visiting scientists. Overall, these results document a clear need to provide plant genetic resources training materials to ensure global plant collections are curated with the best available technologies and techniques.

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Abbreviations: CGIAR, Consultative Group for International Agricultural Research; NGO, nongovernmental organization; NPGS, National Plant Germplasm System.

The future of global plant breeding programs is dependent on having high-quality collections of plant genetic resources available (Byrne et al., 2018). There are 1750 genebanks throughout the world (FAO, 2010; Fu, 2017) that play a role in the acquisition, maintenance, characterization, evaluation, regeneration, preservation, documentation, and distribution of plant genetic resources ranging from elite cultivars and landrace varieties to wild species. These genetic resources are maintained as seeds, field and greenhouse plantings, in vitro cultures, and DNA and are preserved for the long-term in refrigerators, freezers, and liquid nitrogen. These materials are then used for breeding, research, and other applications by government agencies, universities, nongovernmental organizations (NGOs), and the private sector.

A wide range of knowledge and skills are required to successfully conserve and encourage the use of plant genetic resources. Key scientific disciplines that contribute to plant genetic resource management include agronomy, horticulture, genetics and genomics, plant pathology, plant physiology, plant ecology, plant breeding, entomology, and information management. Many professionals who manage and use plant genetic resources have received academic training in related disciplines and then learn specialized skills through on-the-job training. The lack of formal

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training opportunities has resulted in a challenge for genebanks, universities, seed companies, botanic gardens, and other institutions when new plant genetic resource management personnel must be hired (Bretting, 2018).

Some educational materials and programs relevant to plant genetic resources management are currently available. For example, the Centre for Genetic Resources at Wageningen University & Research, the Netherlands, and the Millennium Seed Bank, Kew, UK, provide short-term, in-person training opportunities. The Universities of Georgia, Illinois, and Saskatchewan have resident instruction courses in plant genetic resources conservation and use. The websites of Bioversity International (https://www.bioversityinternational.org/) and the Crop Trust (https://www.croptrust.org/) provide a variety of videos, fact sheets, and conservation strategies for several crops, but they are not organized into a coordinated training program. To our knowledge, the University of the Philippines Los Baños and the Universidad Politecnica de Madrid are the only institutions that offer graduate degree programs in plant genetic resource conservation and management. Other initiatives on plant genetic resource management are scattered across various websites, cover only portions of the relevant topics, or are not accessible to all learners. Despite the existing training resources, FAO of the United Nations has stated that "human resource capacity is still far from adequate at virtually all levels and in all disciplines related to PGRFA [plant genetic resources for food and agriculture] conservation and use." (FAO, 2012).

In response to this challenge, a USDA-National Institute of Food and Agriculture (NIFA) planning conference was convened in Fort Collins, CO, on 24 to 26 Apr. 2018 to develop a framework for a plant genetic resources management training program. The overall program goals were summarized as "to build and sustain the human capacity to appreciate, maintain, and promote utilization of plant genetic resources" and "to educate professionals in principles and practices of genetic resources management, utilization, and conservation" (Volk et al., 2019).

There are many different categories of institutions with personnel who might benefit from access to training materials for plant genetic resource management. The first institutional type is universities (academia) with faculty who perform research and breeding and teach courses covering plant genetic resources conservation and use. Nongovernmental organizations include botanic gardens, nonprofit seed associations, as well as and national and international plant conservation groups, among others. The private sector includes companies that are involved in seed production, distribution, and plant breeding. We also identified three major institutions that maintain plant genebanks. Within the United States, the USDA-ARS National Plant Germplasm System (NPGS) maintains a collection of nearly 600,000 plant accessions representing nearly 16,000 species across 19 locations. The second major plant genebank institutional type is the Consultative Group for International Agricultural Research (CGIAR) partnership of 11 international genebanks focused on conserving specific crops (CGIAR, https://www.genebanks.org/). The third plant genebank institutional type is international and national government genebanks that are not associated with the NPGS.

A survey was developed and distributed electronically to members of the plant genetic resources community, broadly defined, to assess the needs for specific types of training materials and preferred delivery methods. The objective of this work is to provide the results of the survey and place these results in a broader perspective that describes how plant genetic resources training materials could be developed and implemented.

MATERIALS AND METHODS

We developed a survey to assess the need for plant genetic resources training materials, as well as for specific training topics and pedagogical delivery mechanisms for those materials among individuals already associated with plant genetic resources management and use (see the supplemental material). The survey was distributed only in English. Survey questions were formatted and collected with Qualtrics software, and links for survey participation were widely distributed by e-mail through the mailing lists for the USDA-ARS NPGS, international genebank scientists, and members of the National Association for Plant Breeders, American Seed Trade Association, NPGS Crop Germplasm Committees, American Public Gardens Association, American Society for Horticultural Science Working Groups for fruit, vegetable, and ornamental plant breeding, and Crop Science Society of America sections on crop breeding and plant genetic resources. The survey was open for responses for 2 wk in March 2019, and results were collected anonymously. Only one response was allowed per internet protocol (IP) address. Participants were invited to provide their names and e-mail information once the survey was completed to receive a summary of the survey results.

Results from the survey were downloaded from Qualtrics into Microsoft Office Excel 365, filtered, sorted, and then tabulated using JMP 12 (SAS Institute) and graphed in Excel. Responses to the survey were received from total of 622 unique communication devices. A total of 120 survey responses included no data entries, and an additional 77 surveys provided no "institutional type." Those 197 responses were not subject to further analyses.

RESULTS

Profiles for the Respondents

A total of 425 survey respondents listed their institutional type (Table 1), most of which fell into the eight categories listed in the survey. These responses were filtered if survey respondents listed "private citizen/gardener/plant enthusiast" in addition to another institutional category, and the "private citizen/gardener/plant enthusiast" response was

removed so that only a single institutional type was listed. Institutional types with fewer than 10 respondents (K–12 education; private citizen/gardener/plant enthusiast) as well as the "other" category (with 40 respondents) were not included in the subsequent analyses (Tables 1 and 2), due to the small sample size of respondents.

The institutional types included in the subsequent analyses included academia (higher education), US NPGS, CGIAR genebanks, government genebanks (non-NPGS-affiliated), NGO, and the private sector. Of the 189 respondents from academia, 94 were self-described as plant breeders, 19 were plant genetic resource managers, 47 were researchers, 17 were students, six were teachers, three were administrators, one was an information manager, and two listed "other." Genebank (NPGS, CGIAR, government) and NGO respondents were mostly plant genetic resource managers, researchers, plant breeders, and support staff. Private sector respondents were mostly plant breeders and researchers. All the position types within each of the six institutional types were combined in the subsequent analyses.

Of the 425 survey respondents that listed their institutional type, all but one of those listed their geographic region of origin (Table 2). A total of 333 responses originated from the United States and Canada, likely because the survey was distributed in English and the e-mail distribution lists focused on organizations with predominantly US and Canadian memberships. Responses were also received from Asia (31 respondents), Europe (19 respondents), Latin America (16 respondents), North Africa and the Middle East (6 respondents), Oceana (including Australia and New Zealand, 10 respondents), and sub-Saharan Africa (9 respondents) (Table 2).

Table 1. Number of responses to the survey on plant genetic resources training classified according to institutional categories.

Institution	Respondents	Included in the analyses
	no.	
Academia	189	189
US National Plant Germplasm System (NPGS)	95	95
CGIAR†	19	19
Government genebanks (non-NPGS)	52	52
Nongovernmental organization (NGO)	14	14
Private sector	56	56
Private citizen/gardener/plant enthusiast	6	0
K–12 education	1	0
Other	40	0
Total	472	425

† CGIAR, Consultative Group for International Agricultural Research.

Table 2. Number of responses to the survey on plant genetic resources training that were included in the analyses, classified according to region.

Region	Respondents
	no.
USA/Canada	333
Asia	31
Europe	19
Latin America	16
Oceana (including Australia and New Zealand)	10
Sub-Saharan Africa	9
North Africa/Middle East	6
Blank	1
Total	425

Survey questions were developed to assess the need and value of plant genebank training materials. For all questions, respondents were asked if they "strongly agree," "agree," "neither agree nor disagree," "disagree," "strongly disagree," "don't know," or "N/A" with the statements. The percentage of respondents that selected each of the agreement categories for each institutional type are depicted as stacked bar graphs (Fig. 1–4). Data were reported in the form of percentages within each institutional type to not bias the results due to uneven numbers of responses across the six institutional types.

Between 82 and 93% of the respondents across the six institutional types either strongly agreed or agreed that "there is a shortage of high-quality learning materials on plant genetic resources" (Fig. 1). Similarly, between 67 and 93% of the responses across the institutional types either strongly agreed or agreed that "availability of high-quality learning materials on plant genetic resources would provide information useful to me in my current position" (Fig. 2). The third survey question asked if the availability of high-quality learning materials on plant genetic resources would help advance the survey respondent's career (e.g., in a future position or for future responsibilities). The genebank and NGO institutions had higher numbers of respondents that strongly agreed or agreed careers could be advanced (67% [NPGS], 72% [CGIAR], 65% [nongovernment genebanks], and 62% [NGO]) compared with 45% of the private sector and 53% of academia respondents (Fig. 3). We also asked whether the availability of high-quality learning materials on plant genetic resources would be useful in teaching or providing information to others. Between 93 and 100% of the survey respondents either agreed or strongly agreed that learning materials on plant genetic resources would be useful for teaching or sharing information (Fig. 4).

Priorities for Instructional Topics

The second part of the survey analyses focused on determining which topics for training would be most useful to each of the six institutional types. The survey respondents were provided with a list of potential topics and were asked to rank each as either high, medium, or low priority. The following training topics were included in the survey: general concepts and uses of plant genetic diversity

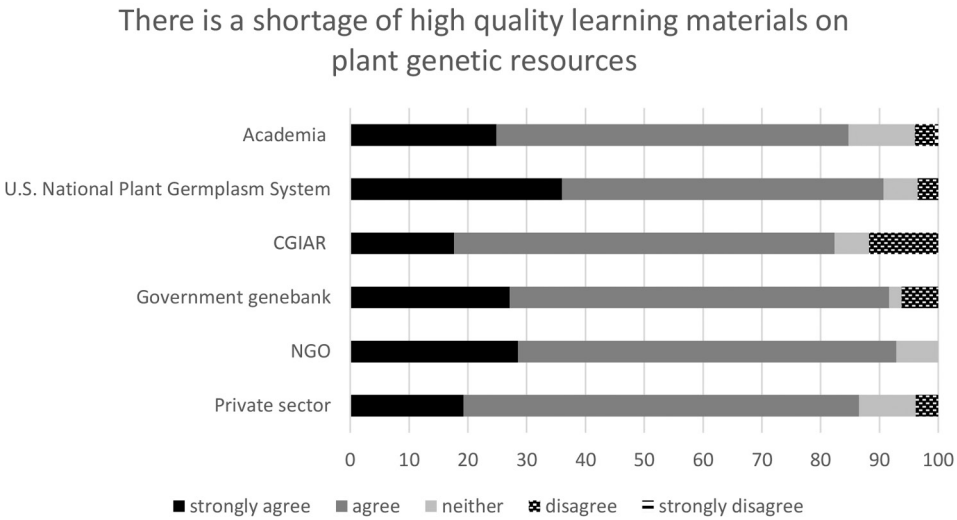

Fig. 1. Percentage of the survey responses received for each institutional type that strongly agreed, agreed, neither agreed nor disagreed, disagreed, or strongly disagreed with the statement "there is a shortage of high-quality learning materials on plant genetic resources." CGIAR, Consultative Group for International Agricultural Research; NGO, nongovernmental organization.

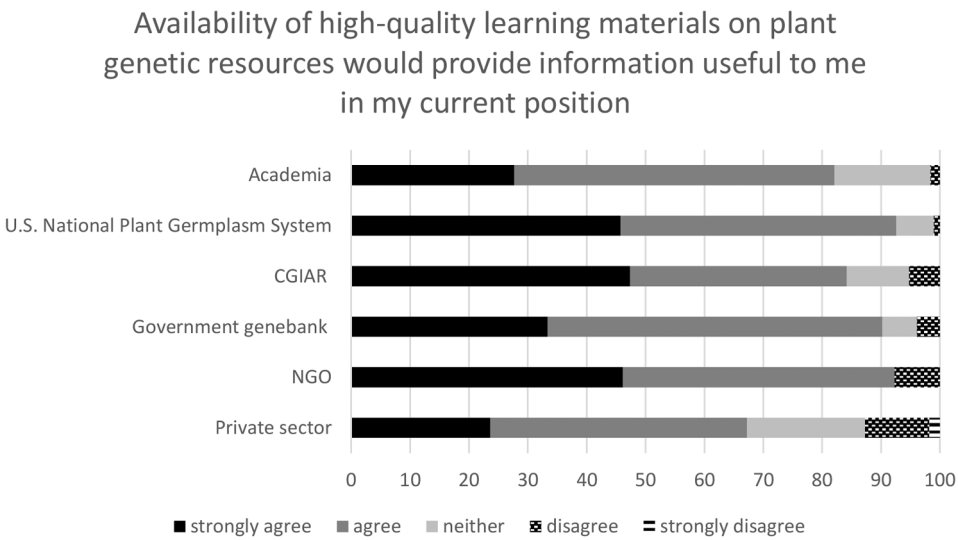

Fig. 2. Percentage of the survey responses received for each institutional type that strongly agreed, agreed, neither agreed nor disagreed, disagreed, or strongly disagreed with the statement "availability of high-quality learning materials on plant genetic resources would provide information useful to me in my current position." CGIAR, Consultative Group for International Agricultural Research; NGO, nongovernmental organization.

(plant genetic diversity), general concepts for managing plant genebanks (genebank management), virtual tour of USDA and/or other genebanks (virtual tours), crop wild relatives, gap analyses of plant genetic resource collections (gap analysis), plant exploration (explorations), preservation techniques for seeds and clonal propagules (germplasm preservation), acquiring and using information associated with accessions (associated information), phenotypic evaluation of accessions (phenotyping), genotypic evaluation of accessions (genotyping), requesting and distributing plant genetic resources (request/distributions), prebreeding with plant genetic resources (prebeeding), intellectual property rights/access and benefit sharing (intellectual property), regulatory issues (e.g., phytosanitary [regulations]), and success stories for use of genebank accessions (success story). The percentage of responses that were classified as high, medium, or low priority was calculated for each topic for each institutional type to adjust for differences in the number of responses received across the institutional types.

The percentage of respondents for each institutional type that listed each training topic as high, medium, or low priority is shown in Fig. 5. Across all the training topics, the percentage of either high- or medium-priority responses ranged from 63 to 100% for the six institutional types. The topics that each of the six institutional types consider to be high priority for >50% of the respondents are summarized below. The respondents from all six institutional types consider crop wild relatives, associated information, phenotyping, and genotyping to be high-priority topics. Genebanking (CGIAR, NPGS,

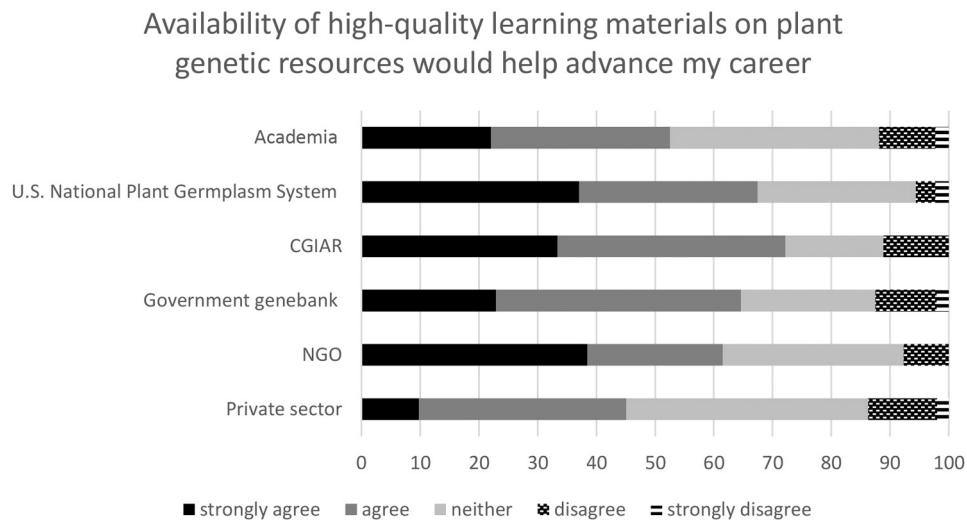

Fig. 3. Percentage of the survey responses received for each institutional type that strongly agreed, agreed, neither agreed nor disagreed, disagreed, or strongly disagreed with the statement "availability of high-quality learning materials on plant genetic resources would help advance my career." CGIAR, Consultative Group for International Agricultural Research; NGO, nongovernmental organization.

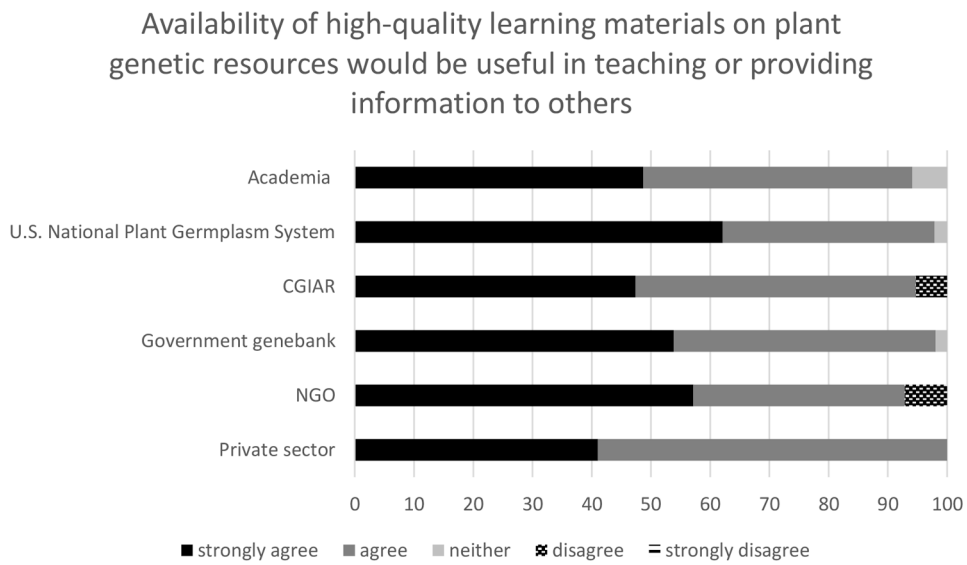

Fig. 4. Percentage of the survey responses received for each institutional type that strongly agreed, agreed, neither agreed nor disagreed, disagreed, or strongly disagreed with the statement "availability of high-quality learning materials on plant genetic resources would be useful in teaching or providing information to others." CGIAR, Consultative Group for International Agricultural Research; NGO, nongovernmental organization.

and government) and NGO respondents also considered gap analyses, germplasm preservation, and intellectual property to be high-priority topics, whereas academia, CGIAR, and government genebank respondents consider plant genetic diversity to be a high-priority topic. The NPGS and government genebank respondents considered genebank management a high priority, whereas academia, CGIAR, and government genebank respondents considered prebreeding a high priority. Regulations was a high-priority topic for the NPGS, CGIAR, and NGO respondents, and requests/distributions were high priority for NGO and private sector respondents. Overall, the virtual tours and success stories had the greatest percentage of low-priority responses.

Audiences for the Training

The survey asked respondents to identify the primary audiences they think would benefit from the learning materials that would be developed. A total of 474 responses were received, and respondents were allowed to choose multiple categories. For each audience category, the number of responses was divided by 474 total responses and a percentage was calculated. Overall, there was a wide range of audiences that the respondents thought would benefit from the learning materials. Fifty percent or more of the respondents indicated that the following would be the primary audiences: myself (76%), my employees/colleagues (70%), graduate students (89%), undergraduate students (51%), genebank personnel

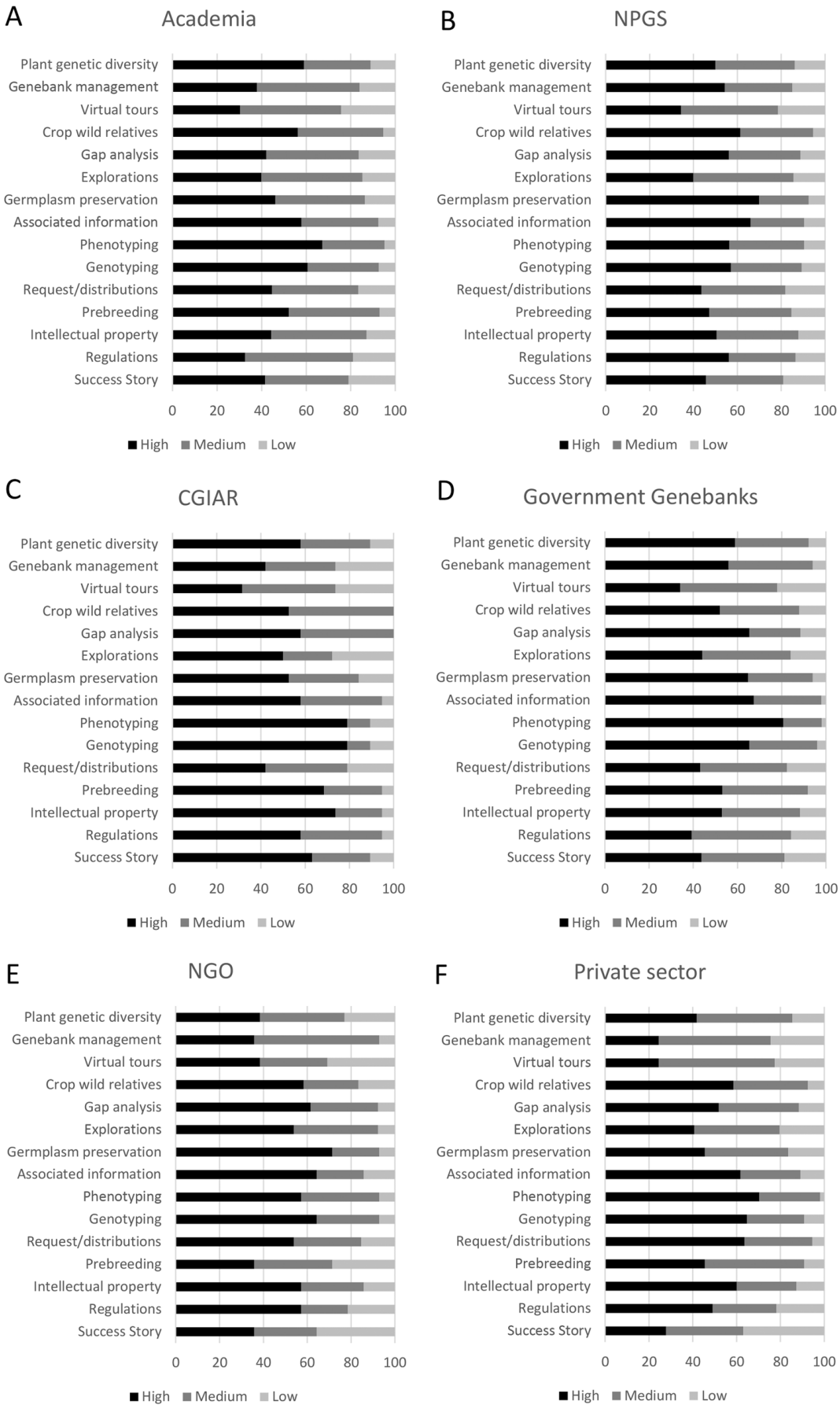

Fig. 5. Percentage of the survey responses from (A) academia, (B) US National Plant Germplasm System (NPGS), (C) Consultative Group for International Agricultural Research (CGIAR), (D) government genebanks (non-NPGS), (E) nongovernmental organizations (NGOs), and (F) the private sector that considered each training topic to be high, medium, or low priority.

(57%), and seed savers, heirloom seed, and fruit organizations (54%) (Fig. 6).

Formats for Training Materials

The survey asked which formats would be most useful for the respondent and their audiences if training materials were available free of charge, and the following categories were listed: short videos on specific topics available online (3–5 min), longer videos on broader topics available online (up to 20 min), web pages text/images, online lesson modules, eBook chapters, links to other online resources (e.g., fact sheets, web pages), webinars, podcasts, and other. The total number of times each training format was identified as of interest was counted and calculated as a percentage of the 474 responses received. The greatest percentage of participants selected short videos (81%), web pages with information (74%), online lessons (56%), and links to other training (55%) (Fig. 7A).

The survey also asked which formats would be most useful for the respondent and their audiences if training materials were available for a fee, and the following categories were listed: face-to-face workshops (1–2 d) (noncredit), face-to-face courses (with academic credit), online courses (noncredit), and online courses (with academic credit). The total number of times each training category was identified as of interest was counted and calculated as a percentage based on the 474 responses received. The greatest percentage of participants selected online courses (noncredit) (64%) and face-to-face workshops (1–2 d, noncredit) (60%) (Fig. 7B).

DISCUSSION

The plant genetic resources training materials survey was widely distributed via the internet, but the majority of the responses received originated from the United States and Canada. We sought to reach a wide range of employees, including those from academia, plant genebanks (US NPGS, CGIAR, non-NPGS government genebanks), the private sector, and NGOs because all of these groups have an interest in the management and/or availability of high-quality plant genetic resources. The total number of people who received the survey is not known because recipients were asked to forward the survey to their colleagues, who might not have been identified in the e-mail lists that queried by the survey. The number of survey responses received and used in the analyses (425) suggested that the sample size of the survey was sufficiently large to assess the needs for plant genetic resource training programs on both a national and international scale.

More than 80% of the respondents in each of the institutional types either strongly agreed or agreed that there is a shortage of training opportunities (Fig. 1), and >80% of the respondents of all institutional types except the private sector (67%) either strongly agreed or agreed that these training materials would be useful in their current position (Fig. 2). More than 90% of the respondents in each institutional type either strongly agreed or agreed that the learning materials would be useful for teaching or providing information to others (Fig. 4). The percentage of respondents that thought these materials would advance their careers varied, with the lowest percentage from the private sector and the largest percentage from genebank employees (Fig. 3).

Overall, there is strong support among a broad range of domestic and international institutions for the development and implementation of plant genebank training materials. Some training needs were deemed high priorities for >50% of the respondents across all the institutional types: accessing associated information, crop wild relatives, genotyping, and phenotyping (Fig. 5). Other training needs varied in the relative importance across the institutional types. The respondents from academia were also interested (high priority > 50%) in prebreeding, which is not surprising because many of these respondents

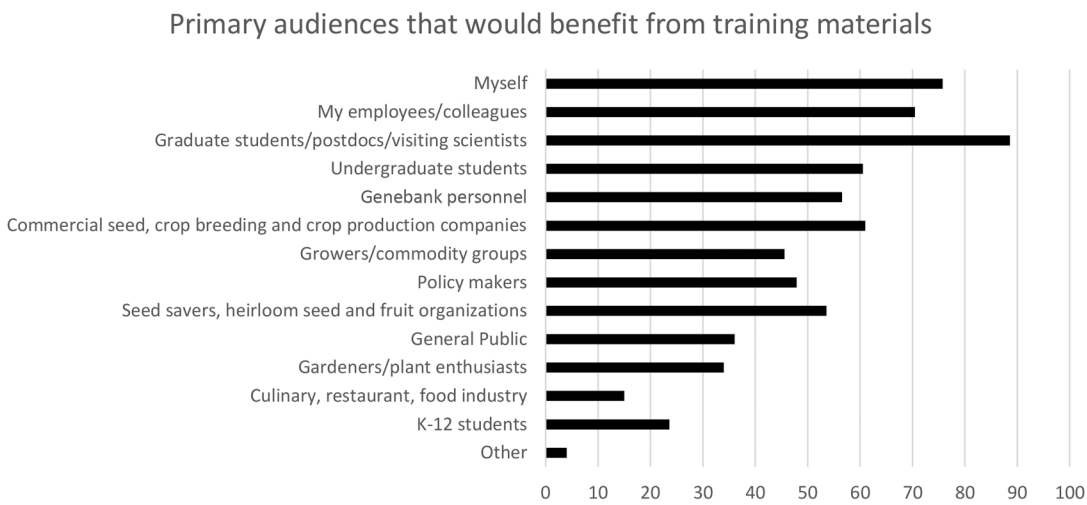

Fig. 6. Percentage of the survey responses that identified the listed primary audiences that would benefit from training materials in plant genetic resources.

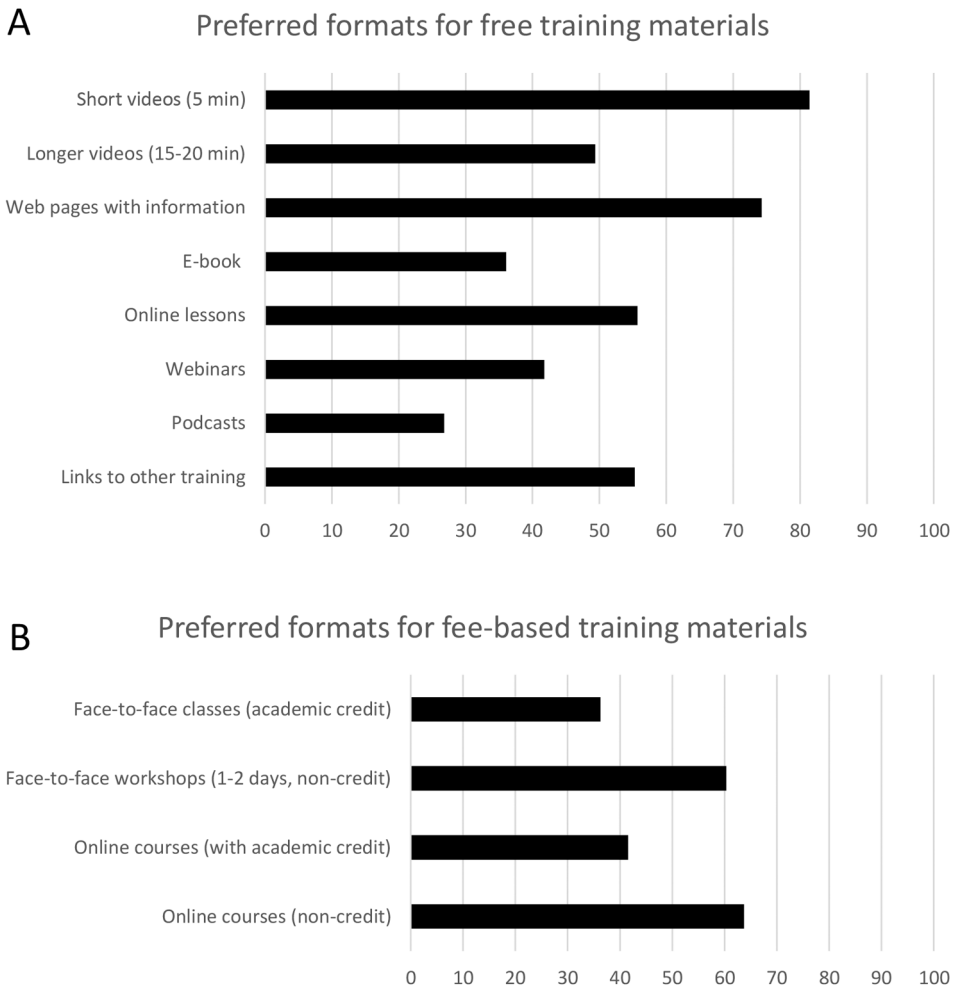

Fig. 7. Percentage of the survey responses that identified the listed formats as useful for (A) free training materials and (B) fee-based training materials.

were plant breeders. Respondents from the private sector were also interested (high priority > 50%) in requests/distributions and prebreeding, and respondents from NGOs were also interested (high priority > 50%) in collection gap analyses, explorations, germplasm preservation, intellectual property, and regulations. The genebank respondents (NPGS, CGIAR, non-NPGS government) considered germplasm preservation, intellectual property, and general concepts in plant genetic diversity as priority topics. These differences among the institutional types are not surprising due to their different missions.

Intellectual property and regulatory issues are high priority training topics. These topics should include information about the legal frameworks of the Convention on Biological Diversity (UN, 1992), International Treaty for Plant Genetic Resources for Food and Agriculture (FAO, 2009), and the Nagoya Protocol on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization to the Convention on Biological Diversity (UN, 2011).

The proposed training materials must be designed to benefit multiple audiences, especially currently employed personnel and graduate students, postdocs, and visiting scientists (Fig. 6). This suggests that the training materials should be focused on audiences who have at least a basic understanding of horticulture, agronomy, genetics, and plant breeding. These training materials could build on the basic principles for those scientific disciplines and apply them towards concepts relating specifically to plant genetic resources.

This survey documented unequivocally that the need for training materials in plant genetic resources is widespread. This wide geographical distribution of the audiences for training does not generally lend itself to traditional university face-to-face coursework; however, online pedagogical approaches could prove to be ideal delivery options. The highest percentage of survey respondents preferred training materials in the form of short videos, web pages with information, online lessons, and links to other training. These types of training materials are not exclusive but rather are complementary. A training materials website could be developed to deliver content (learning objects) organized into general categories, and this content could take the form of webpages

and videos that are freely available and accessible anytime, anywhere. These learning objects could then be assembled into online lessons. The development of training materials will be a collaborative effort with a goal of providing complementary materials to those that are already available. In addition to creating new material, links to other training resources will be provided.

Survey respondents indicated that fee-based or supported, face-to-face workshops and online courses (noncredit) were also of interest (Fig. 7). Online courses (with or without credit) could provide series of online lessons. These online courses could then be delivered through extension or university departments as instructor-led, scheduled classes on a cost-recovery basis. Face-to-face workshops covering specific topics could also be offered periodically in association with conferences, at genebank locations, or associated with universities or other institutions.

In conclusion, the survey results document the international need for quality training materials to educate diverse audiences about plant genetic resource conservation and use. Initial efforts will focus on the key topic areas of crop wild relative and genebank management (broadly defined to include genotyping, phenotyping, and acquiring and using information associated with accessions, as well as germplasm preservation). In addition, resources to educate audiences about key regulatory and intellectual property issues should be made available. Training resources will initially be available through one or more public website as the various components are developed. The components can then be incorporated into existing or new university, workshop, or outreach efforts. It will be necessary to develop close collaborations among genebank, university, NGO, and private sector partners to ensure that learning objectives for the training materials are relevant and widely applicable.

Supplemental Material

The "Survey on Plant Genetic Resources Training Materials," as downloaded directly from the Qualtrics survey software.

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgments

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