# SYNOPSIS OF THE NATIONAL STRATEGIC GERMPLASM AND CULTIVAR COLLECTION ASSESSMENT AND UTILIZATION PLAN

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Introduction to the NPGS Plan

To safeguard and capitalize on the inherent value to agriculture of irreplaceable plant genetic resources, the U.S. National Plant Germplasm System (NPGS) was established. The NPGS maintains, characterizes, evaluates, documents, enhances, and distributes 569,000+ accessions (different genetic types) of 13,000+ species (taxa, including crop wild relatives) at 22 genebanks and support units at 19 geographical locations (Figs. 1, 2). Each NPGS genebank unit is operated by the USDA/ARS, often in partnership with numerous land-grant universities. The NPGS also conducts applied research to devise more efficient and effective management procedures for plant genetic resources (PGR; synonymous with plant germplasm); to add value to PGR through characterization and/or evaluation; and, in some cases, improve PGR via genetic enhancement (Byrne et al., 2018).

**The USDA/ARS National Plant Germplasm System (NPGS)**

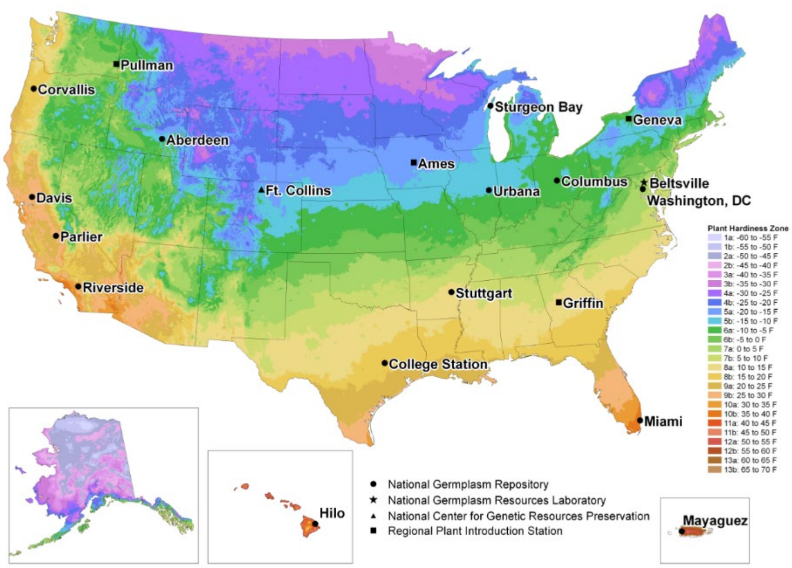



**Fig. 1** The USDA/ARS National Plant Germplasm System (NPGS). The locations of individual NPGS genebank units are projected on the USDA/ARS Plant Hardiness Zone Map. The College Station, Geneva, and Urbana locations each host two separate genebank units.

The 2018 Farm Bill directed the USDA to "develop and implement a national strategic germplasm and cultivar collection assessment and utilization plan that takes into consideration the resources and research necessary to address the significant backlog of characterization and maintenance of existing accessions considered to be critical to preserve the viability of, and public access to, germplasm and cultivars." In response, a National Strategic Germplasm and Cultivar Collection Assessment and Utilization Plan ("Plan" hereafter) was developed in the form of three documents. The current document, "Synopsis of the National Strategic Germplasm and Cultivar Collection Assessment and Utilization Plan" (hereafter termed "Synopsis"), summarizes strategies for how the NPGS will accomplish its mission of conserving PGR and enabling their use while reducing and avoiding the backlogs that could prevent PGR and associated data from being publicly available. This Synopsis is an abridgement of two companion documents that provide extensive details and supporting information for the Plan: the

"National Strategic Germplasm and Cultivar Collection Assessment and Utilization Plan: The Technical Details document, Analyses, and Approaches" (hereafter termed "Technical Details") and the "National Strategic Germplasm and Cultivar Collection Assessment and Utilization Plan: Supplemental Crop and Crop Wild Relative Collections Data" (hereinafter termed "Supplemental Data"). *Notably, the costs listed herein to implement this Plan are estimated and do not constitute a USDA request for funding.*

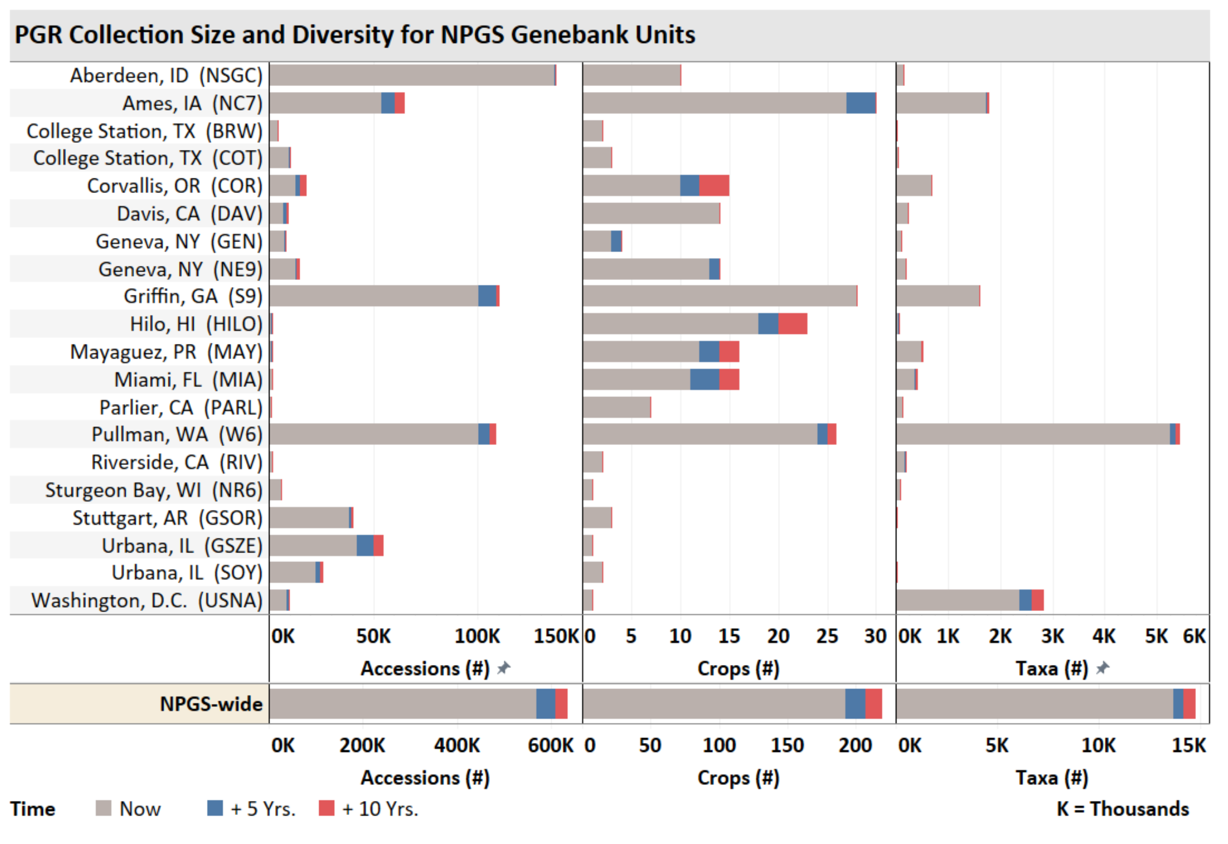



**Fig. 2**. For individual genebank units, listed in the left-hand column by their geographical locations; the current numbers of PGR accessions managed; numbers of crops (as defined by PGR managers) corresponding to those accessions; and numbers of taxa (e.g., species, subspecies, varieties) corresponding to those accessions are shown by gray bars. The estimated increases at +5 years for those metrics are shown by blue bars, and at +10 years by rust red bars. The total NPGS values for the preceding metrics are shown in the bottom row of the figure.

To formulate the strategy for the Plan, quantitative metrics developed by the NPGS or by international genebanks managers (e.g., Engels et al., 2003; Reed et al., 2004; Rao et al., 2006; Hay et al., 2021; Lusty et al., 2021) were applied to assess the current status, support, capacities, and performance of the NPGS's PGR management program and to identify operational backlogs and quality deficiencies. Based on the extensive dataset from that assessment, input from technical experts, and recommendations from the National Genetic Resources Advisory Council (NGRAC) and the National Plant Germplasm Coordinating Committee (NPGCC), NPGS staff and leadership formulated the Plan. They identified priorities and strategies, developed approaches, and constructed 5-year and 10-year timelines to reduce current backlogs, avoid future backlogs, strengthen and increase efficiencies of NPGS operations, improve overall quality of NPGS PGR collections, and comprehensively meet the needs of NPGS customers and stakeholders.

Importantly, the current NPGS facilities, infrastructure, skilled and experienced staff, and operational capacities furnish an invaluable foundation for implementing this Plan **(**Fig. 3). Currently, 87 percent of the 569,000+ NPGS PGR accessions are available for distribution; in an average year, ca. 200,000 samples of those accessions are sent to requestors for research, education, and breeding purposes. The origin or "provenance" for most accessions is documented with data accessible through the NPGS's information management system, Germplasm Resources Information Network (GRIN)-Global. Genebanks around the world have adopted GRIN-Global and it is considered to be the international gold standard for PGR information management. Priorities have been identified for conserving in genebanks and in situ the crop wild relatives (CWR) native to the United States. Many seed-propagated accessions have been safeguarded in the NPGS's world-class facility, the National Laboratory for Genetic Resources Preservation (NLGRP). The NLGRP serves as the long-term storage facility for conserving duplicate samples for accessions managed by NPGS genebanks. In collaboration with other NPGS sites, it has developed improved cryopreservation methods for seed and clonally-propagated PGR.

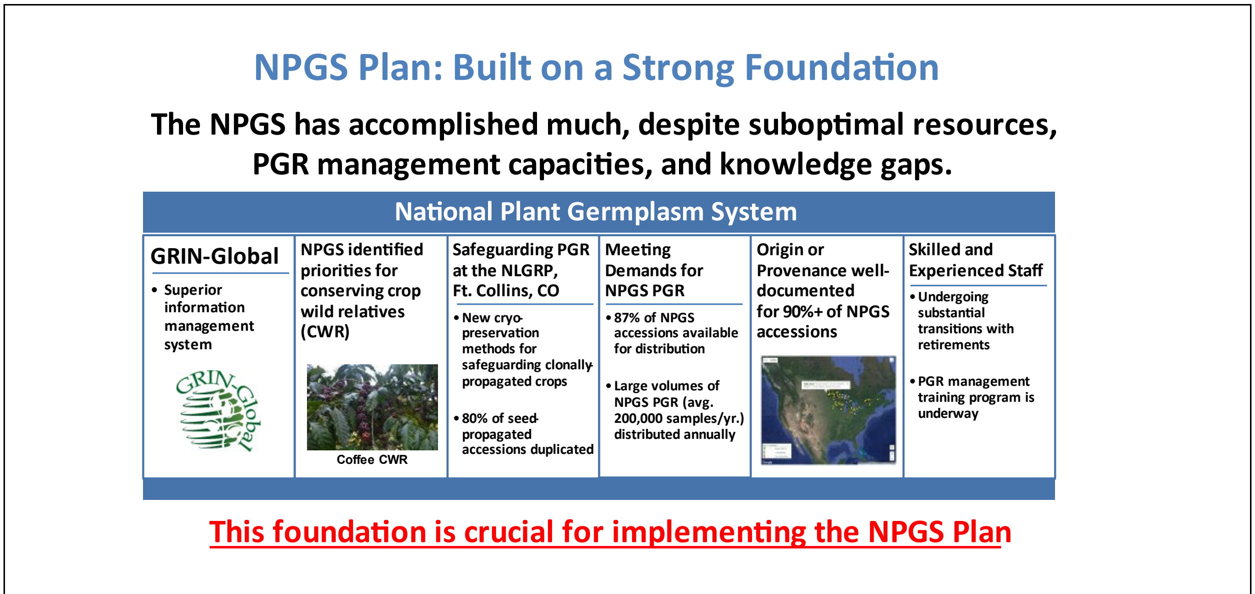



**Fig. 3** The current NPGS staff, infrastructure (including GRIN-Global, National Laboratory for Genetic Resources Preservation, etc.) and the NPGS's recent achievements (e.g., crop wild relative priorities, PGR duplication in long-term storage, availability for distribution) comprise a strong foundation for implementing the NPGS Plan.

Extensive details for the overall organization, data, analyses, strategies, and approaches underlying the Plan can be found in the Technical Details document. This Synopsis document presents the following overall strategies for achieving the outcomes of reducing backlogs and strengthening the NPGS's collection quality:

- Strategically expanding NPGS PGR management capacities;
- Increasing NPGS operational efficiencies; and

- Integrating and expanding NPGS PGR genotypic characterization, phenotypic evaluation, and genetic enhancement operations.

The Plan is organized according to three general operational components of PGR management: Maintenance, Characterization and Evaluation, and Genetic Enhancement, plus applied research to accomplish these operations more efficiently and effectively (Fig. 4). For optimal progress and success, diverse PGR management operations should be closely integrated and coordinated across different crops and within and across different NPGS genebank units. Following the Farm Bill directive, Maintenance and Characterization and Evaluation can be considered roughly co-equal in importance for implementing the Plan, and for generating information crucial for successfully implementing Genetic Enhancement programs.

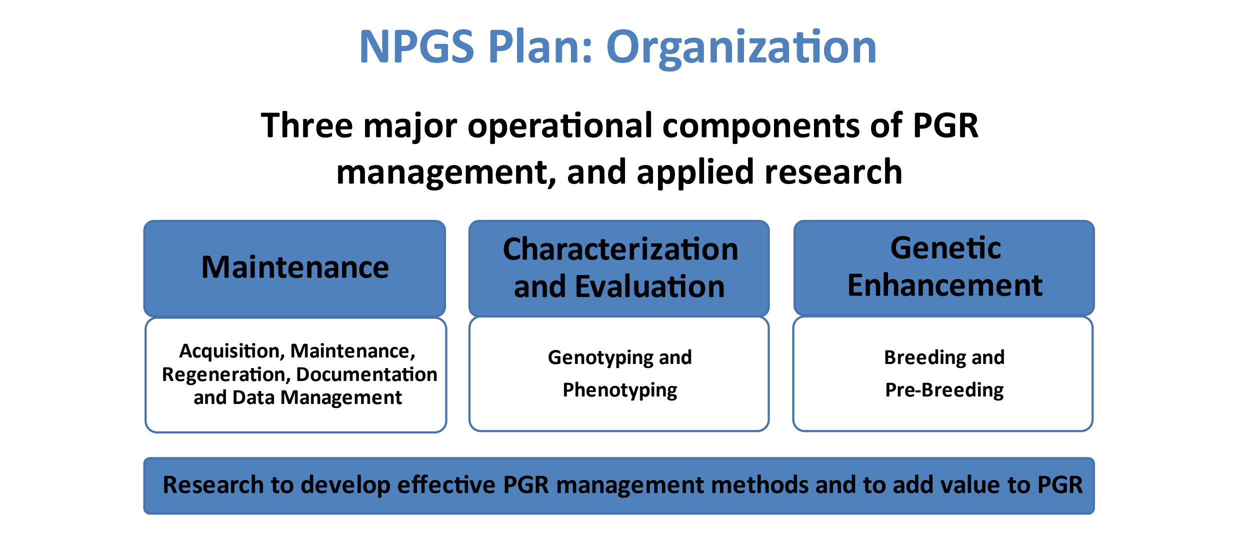



**Fig. 4** The NPGS Plan is organized according to plant genetic resource (PGR) management components (e.g., Acquisition, Regeneration, etc.) that can be grouped under the major headings of Maintenance, Characterization and Evaluation, and Genetic Enhancement. The individual PGR management components listed in this figure are covered in depth in the Technical Details document. Applied research conducted as part of this Plan focuses on developing effective PGR management methods and generating information (characterization and evaluation) and genetically-enhanced populations that add value to NPGS PGR.

Strategically expanding NPGS PGR management capacities

The data in the Technical Details document describe the backlogs for numerous NPGS PGR management operations and the suboptimal quality of some PGR collections. The NPGS's currently inadequate operational resources and infrastructure are primary causes of those deficiencies. Furthermore, progress in PGR management has been hampered by inadequate knowledge of the biological and genetic properties for some species, especially for CWR, and a corresponding lack of effective PGR management methods (Fig. 5). To reduce and avoid such backlogs and improve the NPGS collection quality, the capacities to maintain (i.e., store, back-up, assess quality, regenerate), characterize, and evaluate PGR must be strategically expanded during the next +10 years (Fig. 5), and supported by substantial increases in the NPGS's budgets (Fig. 6; *The costs to implement this plan are estimated and do not constitute a USDA request for funding*). Current partnerships with universities and the private sector must be strengthened and new partnerships with Tribal Nations and non-governmental (NGOs) and international organizations must be established to efficiently strengthen PGR management capacities (Fig. 7). International standards for PGR management should be followed to enable successful international partnerships.

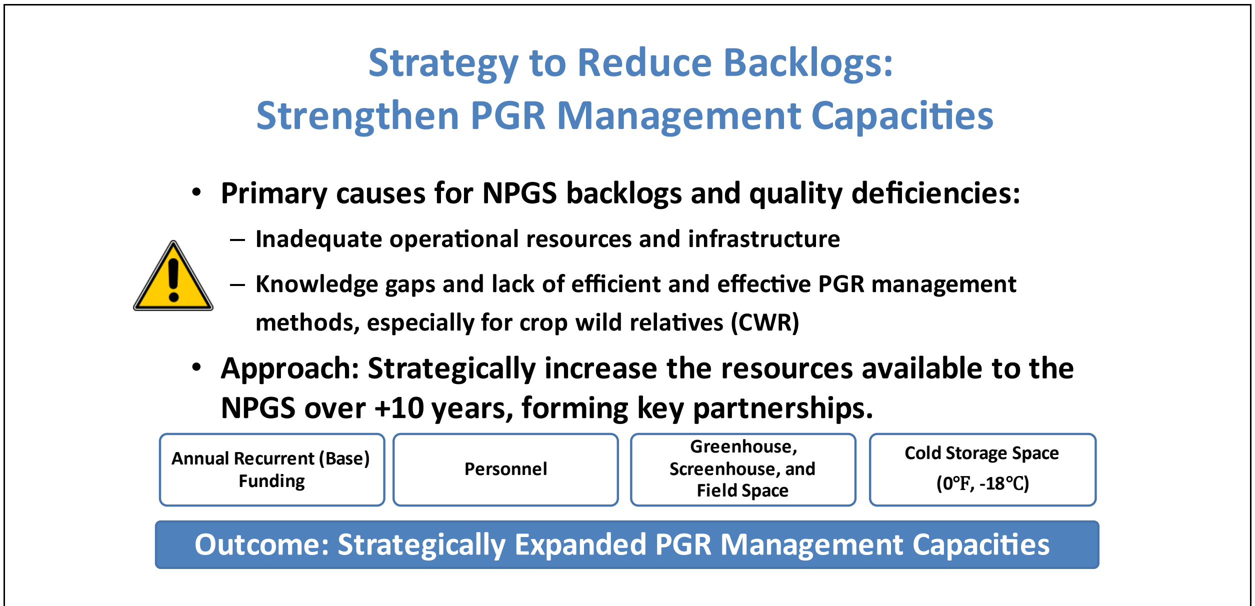



**Fig. 5** A primary strategy to reduce the current NPGS backlogs and quality deficiencies in PGR maintenance, characterization, etc., is increasing the resources (budget, personnel, infrastructure) available to the NPGS, and forming additional partnerships to address those goals. These actions will achieve the outcome of strategically expanded PGR management capacities.

Incrementally enlarging the NPGS's annual recurrent (base) funding (Figs. 6, 8, and data in the Technical Details document) over the 10 years of the Plan will enable the NPGS to strategically expand its PGR management capacity. Genebank units have estimated budgetary and infrastructural needs according to:

- the size and complexity of current operational backlogs;
- assessments of operational efficiencies;
- forecasts for the relative growth of PGR collections;
- the diversity and biological features of the PGR managed;
- the role of the genebank unit in the NPGS; and
- needs for applied research.

Some genebank units will not require large funding increases (e.g., Aberdeen, Sturgeon Bay, Stuttgart) but others will require major increases (e.g., Ames, Beltsville, Fort Collins, and Pullman) to reduce and avoid backlogs, conform to NPGS and international standards and practices, and assume additional PGR management responsibilities. Similarly, cold storage, greenhouse, screenhouse, and field space for genebank units must be expanded strategically. In particular, genebank units at Ames, Fort Collins, Griffin, and Pullman need substantially larger cold storage space; Pullman and Davis require significantly more field space; and numerous genebank units need more greenhouse and screenhouse space to house and/or regenerate PGR requiring special growth conditions and/or with complicated reproductive modes (Fig. 8).

**Additional Resources Needed to Reduce Backlogs, Strengthen PGR Management Capacities, and Conduct PGR Genetic Enhancement**

**a. NPGS Plant Genetic Resource Management Funding (NTL $)**

| | | | Now | + 5 Yrs. | +10 Yrs. |
|---|---|---|---|---|---|
| Total Annual Recurrent Funding | Operations & Applied Research | Overall Operations | $38.01 M | | |
| | | Maintenance | | $55.46 M | $67.71 M |
| | | Characterization | | $1.80 M | $1.80 M |
| | | Trait Evaluations | | $25.00 M | $25.00 M |
| | | ***sub-total*** | ***$38.01 M*** | ***$82.26 M*** | ***$94.51 M*** |
| | Enhancement & Characterization | Genetic Enhancement (HIGH) | | $150.00 M | $150.00 M |
| | | Genotypic Characterization | | | |
| | | Whole Genome Sequencing* | | | |
| | | ***sub-total*** | | ***$150.00 M*** | ***$150.00 M*** |
| | | **Total** | ***$38.01 M*** | ***$232.26 M*** | ***$244.51 M*** |

| | | | Now | + 5 Yrs. | +10 Yrs. | One-Time |
|---|---|---|---|---|---|---|
| Additional Funding | Operations & Applied Research | Overall Operations | | | | |
| | | Maintenance | | $17.45 M | $12.25 M | |
| | | Characterization | | $1.80 M | | |
| | | Trait Evaluations | | $25.00 M | | |
| | | ***sub-total*** | | ***$44.25 M*** | ***$12.25 M*** | |
| | Enhancement & Characterization | Genetic Enhancement (HIGH) | | $150.00 M | | |
| | | Genotypic Characterization | | | | $16.67 M |
| | | Whole Genome Sequencing* | | | | $40.50 M |
| | | ***sub-total*** | | ***$150.00 M*** | | ***$57.17 M*** |
| | | **Total** | | ***$194.25 M*** | ***$12.25 M*** | ***$57.17 M*** |

**M = Millions. *optional characterization**

**b. NPGS Personnel and Infrastructural Needs**

| | | Now | + 5 Yrs. | + 10 Yrs. |
|---|---|---|---|---|
| **Personnel** | Personnel Levels (# FTE) | 302 | 444 | 518 |
| **Cold Storage & Growing Space** | Field Space (acres) | 2,333 | 2,528 | 2,719 |
| | Greenhouse & Enclosed Space (ft2) | 264,565 | 365,747 | 430,207 |
| | Cold storage space (ft3) | 380,230 | 498,154 | 582,397 |

**Fig. 6a,** NPGS Plant Genetic Resource Management Funding (net-to-location, NTL), summarizes in millions of dollars (M) the funding needed to implement this Plan. *The costs to implement this plan are estimated and do not constitute a USDA request for funding.* In the top half of Fig 6a, titled "Total Annual Recurrent Funding" the left-most column, "Now", depicts current levels of annual recurrent funding. The estimated annual recurrent funding needed in the future are in the columns to the right labeled "+5 Yrs." and "+10 Yrs." respectively. Sub-headings labelled "Operations & Applied Research" and "Enhancement & Characterization" distinguish two major categories of NPGS PGR activities, further broken down by different combined operational and research components in the adjacent column. The bottom half of the Figure, titled "Additional Funding", lists the increases of annual recurrent NPGS funding above current levels needed to expand specific NPGS operations and applied research components at the specified time intervals during the Plan ("+5 Yrs." and "+10 Yrs."). The cost estimate for supporting genetic enhancement operations for ca. 100 crops is presented at the highest of the range of costs estimated for those activities (row labelled "HIGH"). The right-most column labeled "One-Time" indicates that the funding needed for some steps in genotypic characterization is not recurrent. "Whole Genome Sequencing" is marked with an asterisk because it is an optional operation. More details for the funding are herein and in the Technical Details document. **Fig. 6b,** NPGS Personnel and Infrastructural Needs, summarizes the expanded personnel (# FTE) staffing levels and infrastructural capacities (field space, greenhouse and enclosed space, and cold storage space) needed to implement the Plan. The personnel and infrastructural capacities available currently are shown in the left-most column, "Now"; and adjacent columns present the needs at 5 years ("+5 Yrs.") and 10 years ("+10 Yrs.") after beginning to implement the Plan. This document and the Technical Details document provide additional details for the Plan's personnel and infrastructural needs.

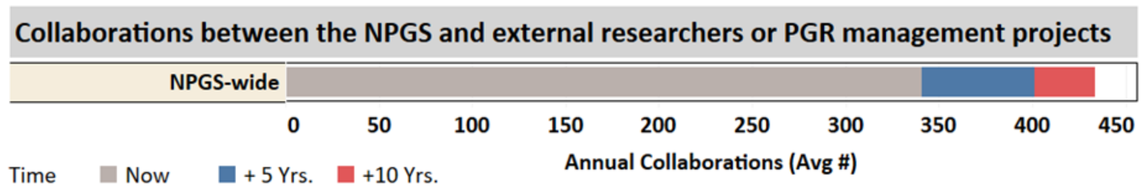



**Fig. 7.** The current average annual numbers of formal NPGS research and PGR management collaborations with external research and PGR management projects or organizations are shown by gray bars. The goals for collaborations at +5 years are shown by blue bars and for +10 years by rust red bars.

The substantial needs for increased NPGS staffing and for adapting to numerous upcoming NPGS staff retirements (ca. 1/3 will have retired by +5 years) represent major organizational and operational challenges. For the Plan strategy to be implemented successfully, additional NPGS personnel, especially curators, must be recruited, trained (particularly in advanced information management approaches with GRIN-Global), and retained (Fig. 9**,** Technical Details document).

It is an NPGS priority for curators and PGR managers to become the national and international authorities for the plant genetic diversity for which they are stewards. Those needs are particularly critical for genebank units such as Ames, Fort Collins, and Pullman, for reasons cited earlier for expanded budgets and infrastructure. Consequently, it is a priority to expand over the next +5 to +10 years the current training program for PGR management, delivered primarily through distance learning by NPGS staff and university cooperators e.g., GRIN-U, https://grin-u.org/. The online, virtual format should achieve the impacts of reaching more personnel, particularly from under-represented minority groups who may not have had access to in-person university classes in the past, and exploring new aspects of PGR management and genetic, biological, and information technologies as they arise in the future.

The lack of effective core PGR maintenance methods is directly responsible for some of the most severe operational backlogs in the NPGS although inadequate PGR management capacity has also contributed to those backlogs. Consequently, applied research is crucial for attaining the priority goals of this Plan through:

- developing the new, more efficient and effective technical approaches and methods needed to reduce or eliminate operational backlogs for recurrent PGR maintenance operations; and
- generating information about PGR that facilitates their ready use in plant research and crop breeding.

The expanded NPGS budgets, personnel staffing, and infrastructure for +5 and +10 years (Figs. 8, 9, and the Technical Details document) will strategically increase the applied research capacity needed to implement the Plan. For example, improved methods are crucial for long-term maintenance (ideally, cryopreservation) and back-ups of clonally propagated PGR and those with seeds that cannot be preserved under standard reduced-temperature regimens. Research to develop new seed treatments that improve germination of historical/legacy seeds could rescue invaluable genes and traits that might be otherwise lost.

## Resources to Reduce Backlogs and Strengthen PGR Management Capacities

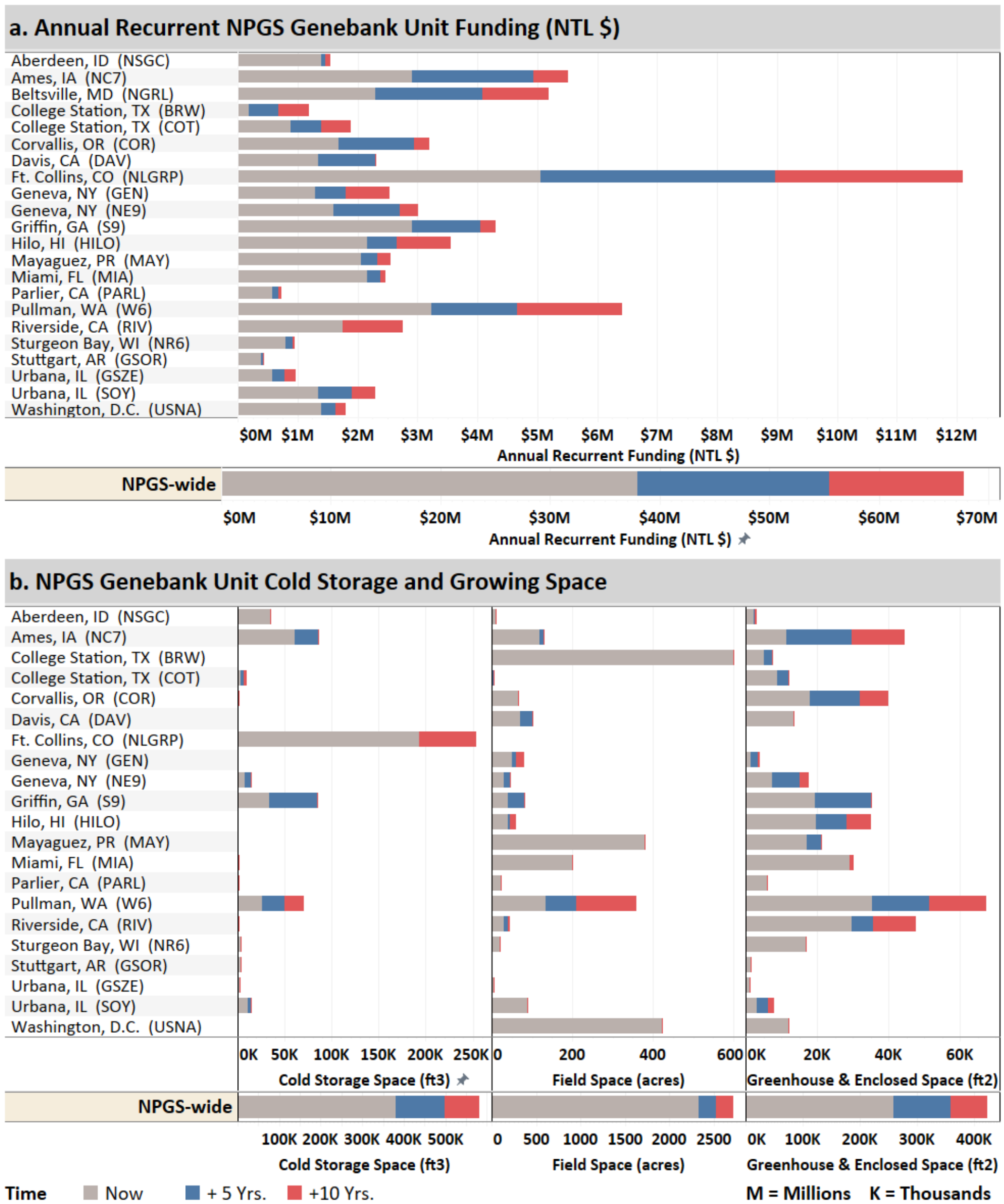



**Fig. 8** summarizes the additional resources needed at each of the 22 NPGS genebank units (listed in the left-most column) to achieve the outcomes of the NPGS Plan. In **Fig. 8a**, the current values for the annual recurrent funding (Net-to-Location, NTL) for overall operations at the NPGS individual genebank units, listed alphabetically by their geographical locations, are shown by gray bars. The estimated increases needed to attain the PGR maintenance and applied research goals of the Plan at +5 years are shown by blue bars, and at +10 years by the rust red bars. An overall summary of the NPGS total annual recurrent funding (NTL) is included at the bottom. *The costs to implement this plan are estimated and do not constitute a USDA request for funding.*

In **Fig. 8b**, the current volumes for the NPGS cold storage space (in $ft^3$) used by NPGS operations at individual genebank units, are shown by gray bars. The estimated increases in space needed to attain the goals of the Plan at +5 years are shown by blue bars, and at +10 years by rust red bars. The current areas for the field space (in acres) and for the greenhouse and enclosed space (e.g., screenhouses; in $ft^2$) used by NPGS operations are shown by the gray bars. The estimated increases for field, greenhouse, and enclosed space needed to attain the goals of the Plan at +5 years are shown by blue bars, and at +10 years by rust red bars. The total NPGS values for the preceding metrics are shown in the bottom row of the figure.

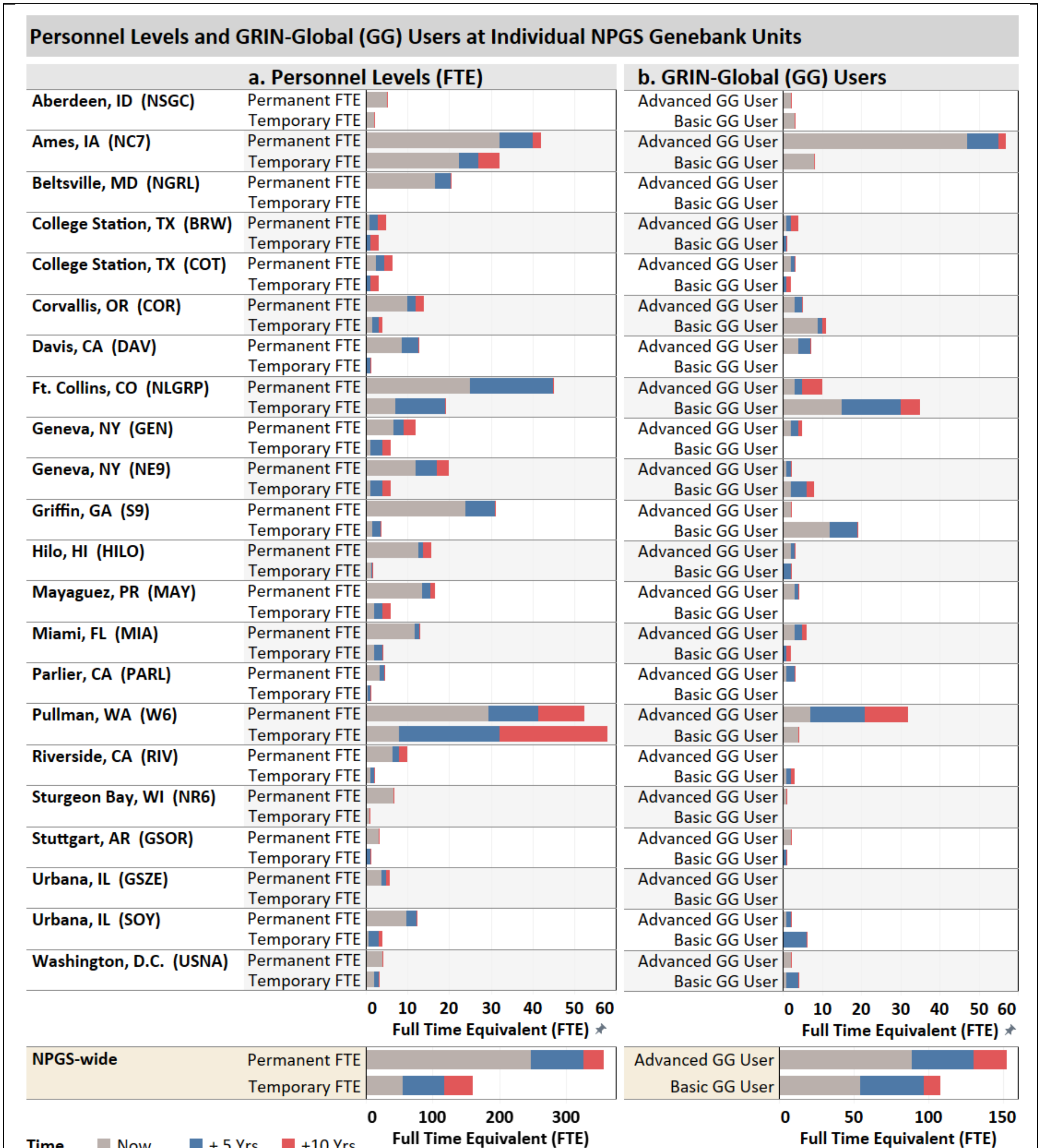



**Fig. 9** depicts the additional personnel and, specifically, personnel trained to use the GRIN-Global information management system, needed by individual NPGS genebank units to attain the goals to the Plan. In **Fig. 9a**, for individual genebank units, listed alphabetically in the left-most column by their geographical locations, the current numbers of permanent and temporary staff members (full-time equivalents, FTEs) are shown by gray bar, goals for +5 years by blue bars, and for +10 years by rust red bars. The total NPGS values for the preceding metrics are shown in the bottom rows of the figure.

In **Fig. 9b**, the numbers of advanced and basic users of the NPGS's information management system GRIN-Global (GG) Curator Tool are shown by gray bars, goals for +5 years by blue bars, and for +10 years by rust red bars. The total NPGS values for the preceding metrics are shown in the bottom rows of the figure.

The information associated with PGR is almost as valuable as the PGR itself (Weise et al. 2020); consequently, maintaining and delivering those data have long been NPGS priorities. As more information accumulates through this Plan's expanded research, as well as genotypic characterization and phenotypic evaluations (see below), the NPGS can better recommend to users the optimal PGR for particular research and genetic improvement goals. In addition, the NPGS can serve as a more effective source for informing food and national security policies. The NPGS is already a key component of the U. S. National Plant Disease Recovery System (Administration of G. W. Bush, 2004), and participates in emergency planning for the use of resistant seed varieties and pesticide control measures to prevent, slow, or stop the spread of high-consequence plant diseases.

Although GRIN-Global is already considered an international "gold standard" for information management, the NPGS will seek to expand its current partnerships with the Crop Trust, other genebanks, and Bioversity International for further development of GRIN-Global. Information from GRIN-Global will continue to be periodically transmitted to the Genesys international information system (https://www.genesys-pgr.org/), the online portal for all information on global genebank samples. In the future, direct connections between GRIN-Global and Genesys will be increased. GRIN-Global's capacity to manage greater volumes of genotypic characterization and phenotypic information will result in expanded partnerships with other ARS information systems that manage crop genome data (e.g., MaizeGDB, the Legume Information System, and other species-specific information) and the Breeding Insight Project (https://www.breedinginsight.org/).

Increasing NPGS Operational Efficiencies:

Increasing operational efficiencies is a critical strategy for reducing backlogs and improving PGR management performance. This has been and will continue to be achieved by structuring the NPGS's PGR collections so that the greatest amount of genetic diversity is represented by the optimal number of accessions. As the data in Fig. 10 and in the Technical Details document show, the NPGS collections will grow strategically and slowly, between 1-1.5 percent per year, during the 10 years of the Plan. Crop Germplasm Committees (CGCs) will provide guidance for priority PGR acquisitions through up-to-date Crop Vulnerability Statements. Based on input from CGCs, other external experts, and NPGS PGR managers, acquiring comprehensive coverage of CWR native to the United States is a priority, and plans have already been formulated to achieve this outcome (see the Technical Details document and Khoury et al., 2020). Acquisitions will also focus on the needs for national security and emergency deployment strategies. As a component of the National Plant Disease Recovery System, the NPGS contributes to responses to high-consequence plant diseases through "the use of resistant seed varieties within a single growing season to sustain a reasonable level of production for economically important crops" (Administration of G. W. Bush, 2004). Acquisitions should thus prioritize locating and obtaining genetic variation of potential value for disease and insect resistance, adaptation to extreme weather, meeting changing consumer needs, and providing economically useful traits.

Genotypic and phenotypic characterization data, ecogeographical information, and origin or provenance information will contribute to efficient PGR acquisition and management. These data will serve to identify gaps in the NPGS collections that establish priorities for incorporating new acquisitions; manage current NPGS collections and assemble new crop collections (e.g., for hemp and coffee) with optimal size and genetic diversity; and identify genetically redundant accessions that can be safely archived without losing valuable genes or traits.

**Expansion of the NPGS PGR Collection**

| Primary Type of Germplasm | NPGS Genebank Unit | NPGS Collection Size | | | Annual New Acquisitions (Avg # Accessions) | | | Annual Growth Rate | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Now | + 5 Yrs. | + 10 Yrs. | Now | + 5 Yrs. | + 10 Yrs. | Now | + 5 Yrs. | + 10 Yrs. |
| | **NPGS-wide** | **569,197** | **608,384** | **640,414** | **7,934** | **7,840** | **6,408** | **1.4%** | **1.3%** | **1.0%** |
| Managed as Seeds | **PGR specialization** | **523,526** | **557,267** | **583,934** | **7,184** | **6,749** | **5,335** | **1.4%** | **1.2%** | **0.9%** |
| Managed as Seeds | Aberdeen, ID (NSGC) | 136,667 | 136,932 | 137,197 | 206 | 53 | 53 | 0.2% | 0.0% | 0.0% |
| Managed as Seeds | Ames, IA (NC7) | 53,705 | 60,580 | 65,297 | 323 | 1,376 | 945 | 0.6% | 2.3% | 1.4% |
| Managed as Seeds | College Station, TX (COT) | 9,813 | 10,070 | 10,370 | 51 | 51 | 60 | 0.5% | 0.5% | 0.6% |
| Managed as Seeds | Geneva, NY (NE9) | 12,707 | 13,292 | 14,032 | 4 | 117 | 148 | 0.0% | 0.9% | 1.1% |
| Managed as Seeds | Griffin, GA (S9) | 100,181 | 109,044 | 118,030 | 1,714 | 1,773 | 1,797 | 1.7% | 1.6% | 1.5% |
| Managed as Seeds | Parlier, CA (PARL) | 1,178 | 1,278 | 1,509 | 1 | 20 | 46 | 0.1% | 1.6% | 3.1% |
| Managed as Seeds | Pullman, WA (W6) | 100,158 | 106,299 | 109,892 | 1,527 | 1,228 | 719 | 1.5% | 1.2% | 0.7% |
| Managed as Seeds | Sturgeon Bay, WI (NR6) | 5,834 | 5,984 | 6,134 | 30 | 30 | 30 | 0.5% | 0.5% | 0.5% |
| Managed as Seeds | Stuttgart, AR (GSOR) | 38,375 | 39,425 | 40,460 | 208 | 210 | 207 | 0.5% | 0.5% | 0.5% |
| Managed as Seeds | Urbana, IL (GSZE) | 42,411 | 50,000 | 55,000 | 3,000 | 1,518 | 1,000 | 7.1% | 3.0% | 1.8% |
| Managed as Seeds | Urbana, IL (SOY) | 22,497 | 24,363 | 26,013 | 120 | 373 | 330 | 0.5% | 1.5% | 1.3% |
| Managed as Clones | **PGR specialization** | **45,671** | **51,117** | **56,480** | **751** | **1,091** | **1,073** | **1.6%** | **2.1%** | **1.9%** |
| Managed as Clones | College Station, TX (BRW) | 4,108 | 4,300 | 4,500 | 38 | 38 | 40 | 0.9% | 0.9% | 0.9% |
| Managed as Clones | Corvallis, OR (COR) | 12,855 | 13,754 | 14,689 | 179 | 180 | 187 | 1.4% | 1.3% | 1.3% |
| Managed as Clones | Davis, CA (DAV) | 7,064 | 8,494 | 9,854 | 77 | 286 | 272 | 1.1% | 3.4% | 2.8% |
| Managed as Clones | Geneva, NY (GEN) | 7,618 | 7,924 | 8,248 | 43 | 61 | 65 | 0.6% | 0.8% | 0.8% |
| Managed as Clones | Hilo, HI (HILO) | 1,197 | 2,295 | 3,384 | 37 | 222 | 218 | 3.1% | 9.7% | 6.4% |
| Managed as Clones | Mayaguez, PR (MAY) | 1,229 | 1,391 | 1,516 | 51 | 32 | 25 | 4.1% | 2.3% | 1.6% |
| Managed as Clones | Miami, FL (MIA) | 1,545 | 1,812 | 2,082 | 63 | 53 | 54 | 4.1% | 2.9% | 2.6% |
| Managed as Clones | Riverside, CA (RIV) | 1,687 | 1,747 | 1,807 | 12 | 12 | 12 | 0.7% | 0.7% | 0.7% |
| Managed as Clones | Washington, D.C. (USNA) | 8,368 | 9,400 | 10,400 | 250 | 206 | 200 | 3.0% | 2.2% | 1.9% |
| | Beltsville, MD (NGRL) | 0 | 0 | 0 | 500 | 1,006 | 688 | 0.0% | | 3.0%+ |

**Fig. 10** The top row of the figure, shaded light beige, depicts the expansion of the total NPGS collection according to the current numbers of accessions, and estimates for +5 years and for +10 years; the average numbers of accessions currently acquired annually, and estimates for +5 years and for +10 years; and the current annual rate (percentage) growth for the total collection and estimates for +5 years and for +10 years. The same information is then estimated for individual NPGS genebank units, listed alphabetically in the left-most column by their geographical locations, in two groups. The top group encompasses genebank units that primarily manage seed-propagated crops, and the lower group encompasses genebank units that primarily manage clonally-propagated crops. Lavender hues become darker as the annual growth rate increases. Total values for each of the two groups are listed in the first row, shaded light beige, for those groups. The bottom-most row lists the average numbers of accessions collected annually through the plant exploration program operated by the NGRL.

Maintaining PGR through cold storage; quality testing and monitoring of viability and germinability; back-up/duplication; pathogen testing and clean-up; and regeneration/propagation all comprise the core operations of the overall NPGS PGR maintenance program. As illustrated by Fig. 11 and explained at length in the Technical Details document, these operations must be highly integrated for success and efficiency. It is a priority of this Plan to conduct applied research that increases the efficiency and effectiveness of the preceding PGR maintenance operations, because they constitute most of the total cost of PGR management and are critical for the long-term sustainability of the NPGS's PGR collections.

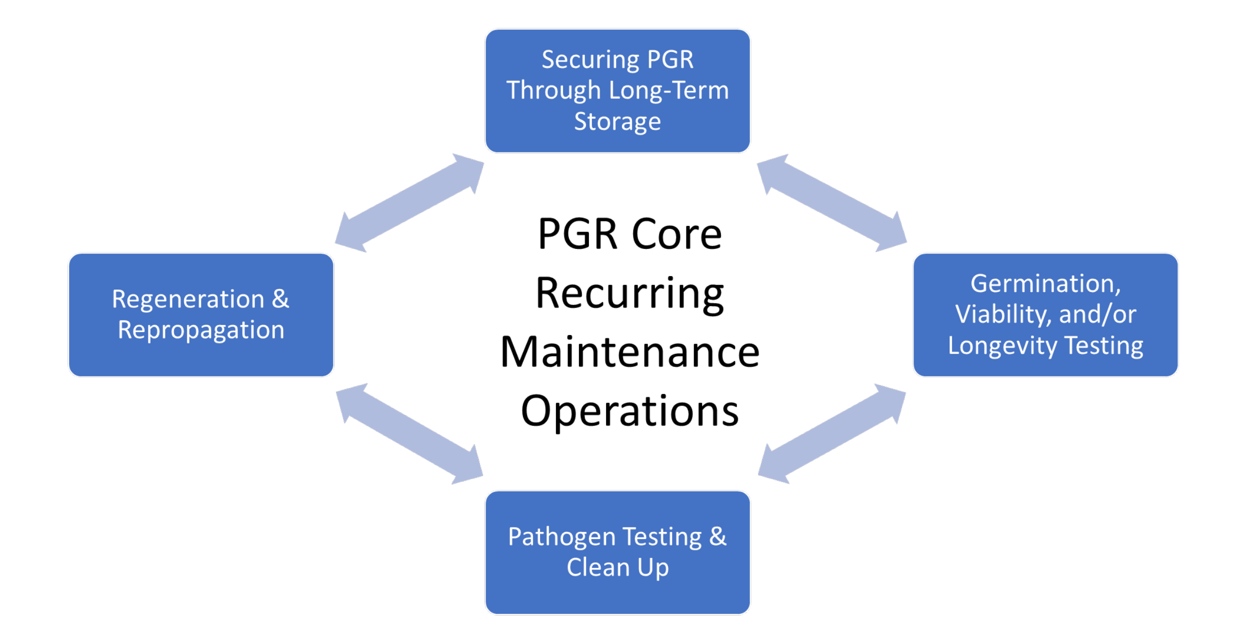



**Fig. 11** As depicted by this figure and explained in further detail in this document and the Technical Details document, the steps "Securing PGR Through Long-Term Storage"; "Germination, Viability, and/or Longevity Testing"; "Pathogen Testing and Clean-up"; and "Regeneration and Repropagation" are integrated, core operations for NPGS PGR maintenance. As depicted by the double-headed arrows in this figure, these PGR maintenance operations in the blue boxes are interdependent and cyclical, i.e., involving recurrent actions often according to a time schedule.

As shown by Fig. 12, the average annual recurrent (base) funding per accession (a proxy for cost) at genebank units devoted primarily to clonally-maintained crops can be several times greater than for units maintaining primarily accessions primarily as seeds, with the highest average annual recurrent funding per accession found at the Hilo, Mayagüez, Miami, and Riverside genebank units, which manage primarily clonally-maintained tropical and subtropical tree crops. Genetically diverse, seed-propagated PGR that are regenerated by costly controlled pollination (e.g., some crops at Ames, Pullman, and Griffin genebank units) on average require more resources than the genetically homogeneous and self-pollinated small grains and rice accessions at Aberdeen and Stuttgart genebank units. These differences are reflected by the budgetary needs projected for +5 and +10 years for individual NPGS genebank units (see the Technical Details document), and by the strategies discussed below and throughout the Plan for achieving the outcomes of reduced operational backlogs and more efficient PGR management.

The NLGRP at Fort Collins plays a pivotal role for long-term storage of duplicate back-up samples, and for monitoring and quality testing (viability, germinability) of the majority of seed-propagated NPGS accessions and those clonally-propagated accessions for which cryopreservation is currently technically feasible. The NLGRP has long served as the paramount national and international genebank unit for applied research to improve the capability for, and efficient monitoring of, quality under long-term storage. As Figs. 8 and 9 indicate, it is a priority of this Plan to increase the operational budget, personnel staffing, and storage infrastructure at the NLGRP to address these system-wide needs most effectively. Applied research priorities include developing effective long-term cold storage methods for clonally-propagated crops via cryopreservation, and for seeds that currently cannot be stored under standard cold and dry conditions. Seed and propagule viability testing capacity at the NLGRP and at other NPGS genebank units also must be expanded, particularly for the Pullman genebank unit, which currently lacks seed testing capabilities.

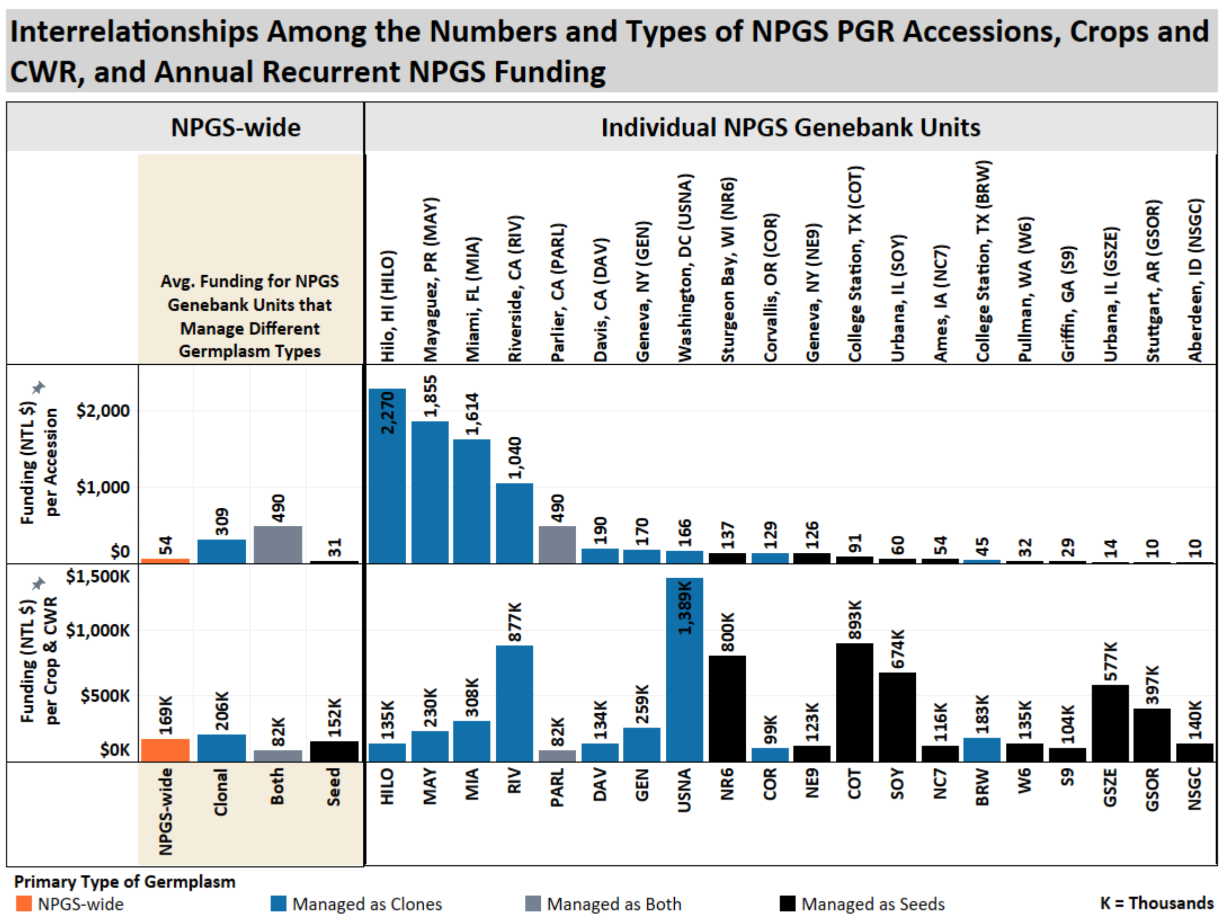



**Fig. 12** depicts interrelationships among the numbers and types of NPGS PGR accessions, crops and crop wild relatives (CWR), and annual recurrent NPGS funding. In the histograms in the second from the top row, the orange bar at the far left depicts the ratio of the current average annual recurrent funding for the overall operations of the total NPGS divided by the current total number of accessions in the NPGS. The other bars in the histogram at the far left of the second from top row summarize the ratios of current average annual recurrent funding for overall operations in NPGS genebank units divided by the current number of accessions at the genebank units that primarily manage i) clonally-propagated PGR (blue bar), ii) an equivalent number of clonally-propagated and seed-propagated PGR (gray bar—just Parlier), and iii) seed-propagated PGR (black bar). The colored bars in the histograms at the right in the second from top row depict the same information for individual genebank units, the names of which are listed above the columns; corresponding acronyms for those names are listed above and below the histogram columns.

The colored bars in the histograms in the bottom row depict the ratios of the current average annual recurrent funding for overall operations in NPGS genebank units to the current numbers of crops and CWR (as defined by PGR managers) at those genebank units. The colored bars at the right in the histograms at the bottom row depict the same information for individual genebank units.

Much of the budgetary, personnel and infrastructural increases (Figs. 8, 9) needed for NPGS genebank sites such as Ames, Parlier, and Pullman, are devoted to strengthening these research and PGR management operations for the hundreds of species that they manage. Expanded regeneration capacities will focus on priority crops and accessions with the longest backlogs (100+ years in some cases), and where the "waiting list" for regeneration exceeds the projected lifespan of the PGR in question (see Technical Details document). Current partnerships with international genebanks such as CIMMYT, commodity groups such as the National Peanut Board, and private-sector vegetable seed companies and trusted service providers (particularly in tropical or subtropical locations) will be expanded to regenerate seed-propagated accessions of crop cultivars to reduce or eliminate backlogs.

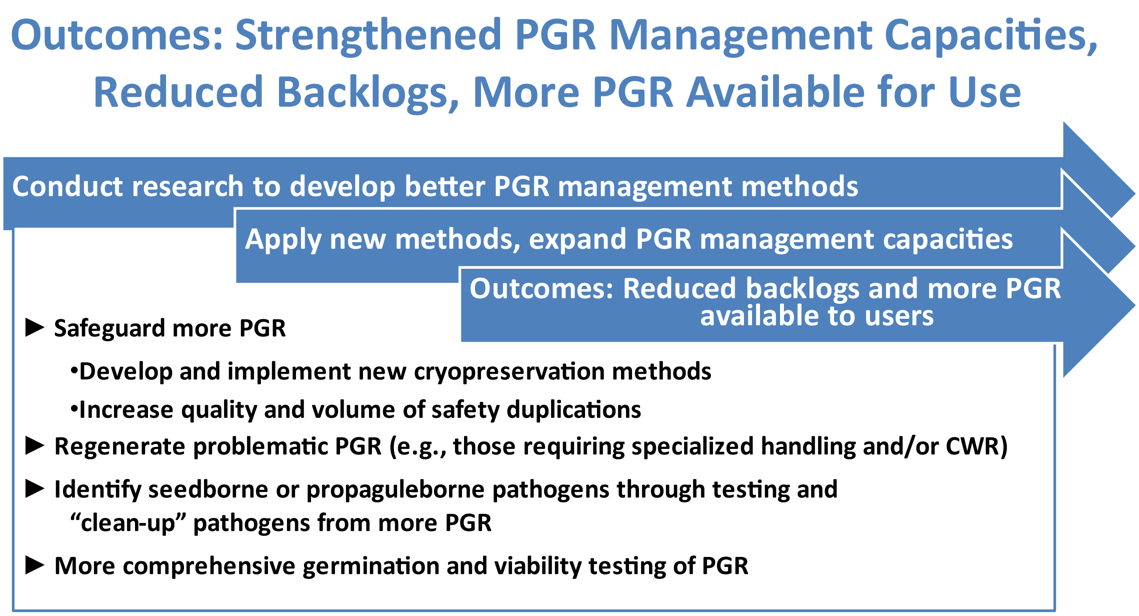



**Fig. 13** depicts by the blue-shaded arrows how the outcomes of reduced NPGS operational backlogs and greater availability of NPGS PGR will be achieved by conducting applied research to develop better PGR management methods and applying those methods and expanding PGR management capacities. Further details for those outcomes are provided by the bulleted list below the blue-shaded arrows.

Developing and applying improved PGR management methods and expanding PGR management capacities will achieve the outcomes of reducing operational backlogs for PGR maintenance and making more, higher-quality NPGS PGR available to researchers, breeders, and educators (Fig. 13). Not only will more PGR be regenerated, but more will be safeguarded through duplication and back-up at the NLGRP via new cryopreservation methods. Seedborne and propagule-borne pathogens will be identified by testing more PGR, and more PGR will be "cleaned-up" from pathogens. More PGR will undergo comprehensive germination and viability testing.

The ecogeographical locations (Fig. 1) of NPGS genebank units and assignment of crops to each have been determined by a combination of historical, budgetary, and crop-specific factors. For example, the NLGRP, the NPGS's site for long-term PGR storage, was established in Fort Collins, Colorado, in 1958 because the relatively low local average temperatures and humidity at that location can contribute to seed longevity. Some of the current NPGS genebank units (e.g., Corvallis, Davis, Hilo, and Riverside) manage collections of clonally-propagated tree crops that were originally assembled by land-grant university faculty at those locations. Managerial responsibilities for those collections were later assumed by USDA/ARS during the 1980s. Other genebank sites (e.g., Ames, Geneva, Griffin, Pullman, and Sturgeon Bay) were established 70+ years ago as USDA/land-grant university partnerships to introduce new row crops and cultivars to diversify crop production in major U. S. production regions (Byrne et al., 2018).

In some cases, the original sites for NPGS genebank units or for specific PGR were suboptimal for successful management, resulting in subsequent relocation of units or crop collections. For example, the entire National Small Grains Collection was relocated during the 1980s from its original site in Beltsville, Maryland, to Aberdeen, Idaho, because the latter location (in the plains of the Pacific Northwest) is a major small grains production region with environmental conditions favorable for successful regenerations and long-term seed storage of small grains. During the 1990s, the *Beta* (beet) PGR collection was relocated from the Ames, Iowa, genebank unit to the unit in Pullman, Washington, for similar reasons.

The accumulated information and analyses conducted for this Plan and presented in the Technical Details document enable assessment of whether current NPGS genebank units are optimal for regenerating or maintaining the crops and species that they have been assigned as well as suggesting alternative approaches for consideration. Such assessments must strategically consider numerous factors including:

- Ecogeographical and economic conditions at genebank unit locations
- Facilities and infrastructure at genebank units
- Genebank unit personnel
- Operational collaborations with other ARS research units
- University partnerships and support for genebank units
- Commodity group and/or industry partnerships and support of genebank units
- Partnerships with NGOs and Tribal Nations
- Congressional and USDA Departmental support for genebank units

For genetically-diverse species with widespread ecogeographical ranges, and for crops cultivated in numerous different production environments, it is likely that no single genebank site is optimal for maintenance or field regeneration of all of the highly diverse accessions assigned to that site. Consequently, it is a priority of this Plan to expand the capacities of the long-season, dry climate genebank unit at Parlier; the Central Ferry, Washington, field operation of the Pullman genebank unit; and the tropical genebank unit at Mayagüez/St. Croix to regenerate more accessions that are maladapted to local growing conditions at other NPGS genebank units.

Because of their historical roles as Plant Introduction Stations, the genebank units at Ames, Geneva, Griffin, and Pullman have managed NPGS vegetable crop PGR for the last 70+ years. During that period, those genebank sites have acquired specialized equipment (e.g., insect-proof field cages for controlled pollinations), customized facilities (such as for cleaning highly diverse seeds), and extensive staff expertise tailored for that mission. Those factors, plus availability of undergraduate student labor and close partnerships and financial support from co-located land-grant universities, have generated cost-efficiencies and economies of scale for managing these mainly seed-propagated PGR (Fig. 12 and the Technical Details document). Nevertheless, the climatic characteristics at some of these sites have not been completely suitable for field regenerations and phenotypic evaluations for some vegetable PGR. Furthermore, during recent years, the quality, quantity, proximity, or cost-effectiveness of available land and student labor has decreased in some cases. Consequently, provided that operational capacities can be expanded, it is a priority of this Plan to achieve the outcome of increasing the proportion of vegetable PGR accessions regenerated at the Parlier or Mayagüez genebank units. For some vegetable crops, responsibilities for managing the entire PGR collection could be transferred from genebank units such as Geneva or Griffin to the Parlier genebank unit.

Integrating and expanding NPGS PGR genotypic characterization, phenotypic evaluation, and genetic enhancement

As recognized by the Congress, knowledge about the genetic diversity and the agronomic and horticultural traits contained in each accession is crucial for successful crop research, breeding, and PGR management. At present, relatively few NPGS accessions have undergone adequate genotypic characterization or trait evaluation. Progress in these areas has relied on ad-hoc support from grants and other temporary funding, which has generally been unevenly applied across collections (see the Technical Details document). Consequently, it is a priority for the NPGS Plan to develop and apply leading-edge genomic and phenomic approaches and technologies to adequately characterize genotypically and evaluate phenotypically most of the NPGS PGR collections during the 10 year period of the Plan (Fig. 14**)**.

**Outcomes: Strengthened PGR Management Capacities, Reduced Backlogs, More Data and PGR Available for Use**

- **PGR characterization (genotyping) and evaluation (phenotyping) generate crucial information for research, breeding, and improved PGR management.**
  - **Relatively few NPGS accessions genotyped now**
  - **Technological limitations, ad-hoc approaches, and lack of adequate standards**
- **Develop and apply leading -edge genomic and phenomic approaches and technologies to characterize genotypically and evaluate phenotypically most NPGS PGR over 10 years.**

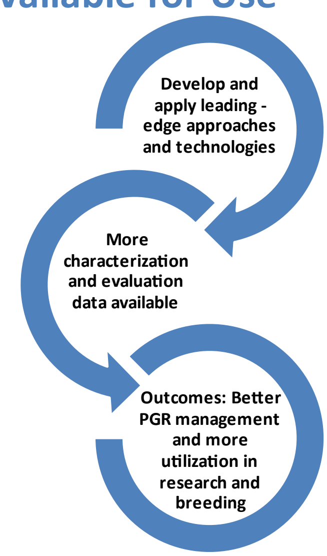



**Fig. 14** depicts, by the blue-shaded circular arrows at the right, the outcomes of better quality NPGS PGR management and greater utilization of NPGS PGR that will be achieved by conducting applied research to develop better PGR characterization and evaluation methods; and applying those methods to NPGS PGR operations to generate more genotypic characterization and phenotypic evaluation data. Further details for the genotypic (or genomic) characterizations and phenotypic (or phenomic) evaluations are provided by the text bullets to the left of the blue-shaded arrows.

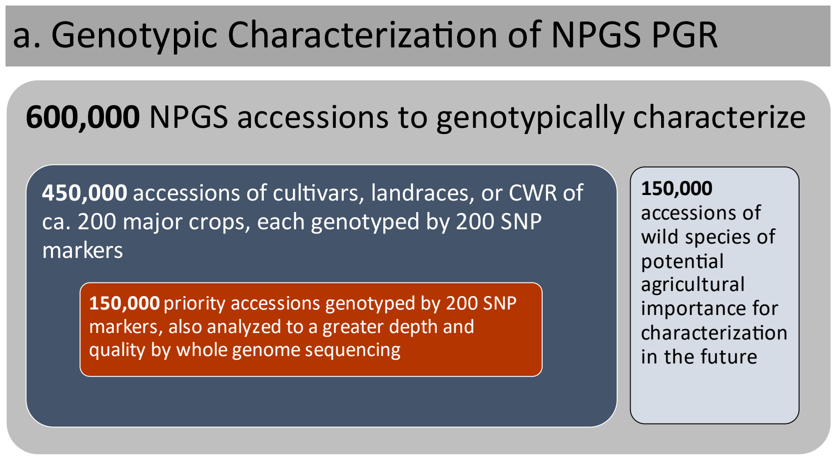
Genotypic characterization will proceed strategically in five phases, as described in Fig. 15 and in the Technical Details document. Where not already available, genetic markers will be developed to genotype about 450,000 accessions of cultivars, landraces, and CWR of ca. 200 major crops. Approximately 200 genetic markers should be sufficient to provide baseline information on relationships between accessions and total genetic diversity in collections, inform decisions on acquisition and maintenance, and stimulate innovation by supporting public- and private-sector crop improvement research. In the process, goals and standards (such as FAO, 2014 for PGR maintenance) for genotypic characterization of PGR will be created with help from CGCs, NPGS personnel, and crop experts. High-volume service laboratories will perform much of the genome sequencing needed to develop the 200 markers, as well as the genotypic characterization of the 450,000 accessions with these new markers. Analytical strategies for some species characterized by populations of genetically heterogeneous, heterozygous accessions are not as well developed compared to homogeneous, homozygous PGR. Nonetheless, significant technical breakthroughs in nucleotide sequencing methods, bioinformatics, and statistical analytical approaches will enable characterization to occur in a timely manner to aid in PGR management and stimulate innovation to meet crop improvement needs. Following the baseline genotyping of 450,000 accessions, a more in-depth sequencing of up to 150,000 of these could be performed to enable identification of high-value genes and potentially important allelic diversity.

Determining the sequence for phenotypic evaluation of traits will be a crop-specific process and follow the priorities from Crop Vulnerability Statements; initial suggestions are listed in the Technical Details document. This list will be further refined in consultation with CGCs, technical steering groups, and other customers and stakeholders to tailor the phenotypic evaluations to particular test locations, carefully balancing cost and benefits. Priorities for phenotypic evaluation will be accorded to traits that can provide resistance or tolerance to severe biotic and abiotic threats and optimize yield/quality of crops crucial to United States and global food security. Phenotypic evaluations will be conducted through expanded partnerships with public- and private-sector organizations that enlist the facilities, equipment, expertise, and operational capacities of those organizations.

New advances in data-collecting technologies and imaging and interpretation software can now capture measurements, or predict expression, of many traits simultaneously, at a vastly reduced price per trait. These new high-throughput phenotyping pipelines are termed "phenomics" and can include imaging and sensing (inexpensive, high resolution, visual, hyperspectral and thermal cameras); measurement platforms (robots, ground vehicles, unoccupied aerial vehicles or UAVs); computer hardware and software (faster processors, image stitching, graphical processing units); and algorithms (temporal analysis, artificial intelligence--AI). The large volumes of data generated by phenomic analytical pipelines, and the extensive post-processing, quality control and interpretation of data, require staff with appropriate expertise and budgetary increases to support the expanded data management capabilities described in the Technical Details document.

The NPGS is pivotal to the collaborative creation and implementation of new digital pipelines to generate and distribute genotypic and phenomic data. These pipelines involve the seamless integration of data generation, storage, analysis, interpretation, and visualization, and ready

**The Approach to Genotypic Characterization of NPGS PGR**



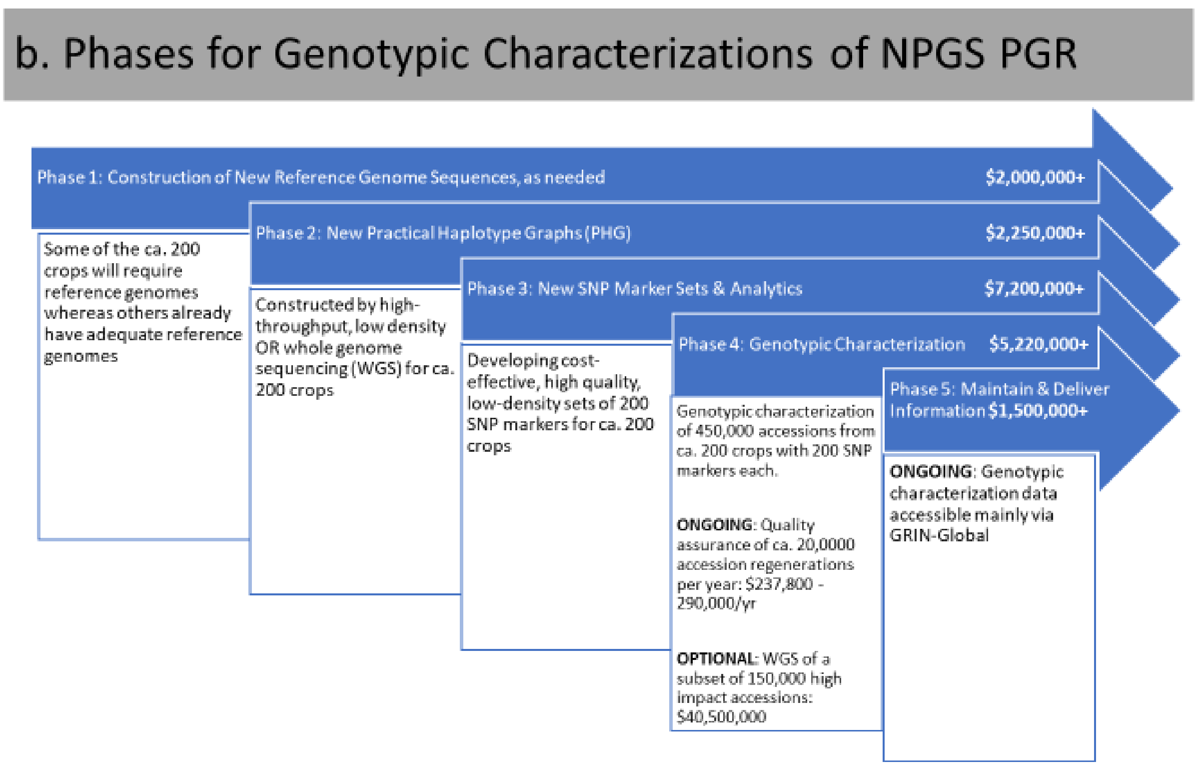




**Fig. 15** provides more information about the extensive genotypic characterizations of NPGS PGR to be conducted by this Plan. **Figure 15a** depicts graphically the plan for genotypic characterization of the current total of ca. 600,000 NPGS accessions (gray bubble). Initially a subset of 450,000 accessions of cultivars, landraces, and CWR of 200 major crops will be genotyped by ~200 markers (navy blue bubble). A priority subset of 150,000 of the preceding 450,000 accessions also will be genotyped by whole genome sequencing (rust red bubble). Finally, 150,000 accessions of wild species (blue/gray bubble) of potential agricultural importance will be genotyped in the future after completion of the prior characterization phases.
**Figure 15b** depicts the five phases for the planned genotypic characterizations of NPGS PGR. Individual phases and their estimated costs are provided in the blue shaded arrows. *The costs to implement this plan are estimated and do not constitute a USDA request for funding.* Additional information for the phases appears in the white boxes beneath the shaft of each individual, blue-shaded phase arrow. The chronological sequence for the phases runs from the earliest, Phase 1 at the left, to the latest, Phase 5 at the right.

access to these data. As the NPGS PGR become more thoroughly described and the accompanying data and information are more readily accessible, AI applications could be developed and applied to autonomously answer queries from PGR requestors/users, and to serve as decision-making tools for PGR management. Consequently, advanced information management and analytical tools could further increase operational efficiency and effectiveness for every genebank unit. Reducing the backlogs in delivering such data and information associated with NPGS PGR can have the impact of stimulating innovation by increasing overall speed and cost-effectiveness of crop research, development, and production enterprises.

The data accumulating from the preceding genotypic characterizations and phenotypic evaluations are critical for identifying optimal PGR, especially of heirloom cultivars and CWR, for incorporation into genetic enhancement programs. Genetic enhancement (or pre-breeding) programs focus on the outcomes of incorporating desired traits from unadapted PGR into adapted breeding populations; adapting PGR to particular environments, in response to emerging biotic and abiotic stresses; and developing novel and useful breeding genepools. This is all done as a prelude to cultivar development. Generating adapted populations or lines derived from NPGS PGR is key for enabling crop breeding programs to effectively exploit the valuable genetic diversity and traits in genebanks. The primary roles that most NPGS genebank units have played in genetic enhancement programs have been to provide the initial genetic diversity needed, and then to conserve and distribute the resulting improved populations or lines to public and private breeding programs. The NPGS Plan envisions more genebank units playing a greater role in future genetic enhancement programs when existing public or private breeding efforts are inadequate to meet the needs for a particular crop. NPGS genebanks could support or lead collaborative genetic enhancement programs with university, NGO, Tribal Nation, other ARS, or private-sector genetic improvement programs. These programs would be focused on the outcomes of broadening the genetic base of U. S. crops, and effectively delivering the intrinsic value of PGR to consumers, farmers, and crop producers.

As explained in the Technical Details document, current genetic enhancement projects, (e.g., the Genetic Enhancement of Maize (GEM) Project), require financial support beyond that currently available to most NPGS genebank units. Therefore, initiating genetic enhancement projects will require substantial additional funding (Fig. 6). As PGR management backlogs are resolved and genotypic characterizations completed, or if maintenance responsibilities for some PGR collections are transferred to other units, the support initially devoted to these activities might be re-assigned to crop genetic enhancement projects. During the 10-year period of the NPGS Plan, joint public and private-sector genetic enhancement programs should be established for as many as 100 significant U.S. crops (see the Technical Details document) based on criteria such as:

- the extent and capacities of current genetic enhancement programs for a crop;
- the breadth of genetic diversity currently available for crop breeding and production;
- a crop's roles in food security;
- its economic value;
- the severity of threats to a crop from biotic and abiotic stresses.

Delivery of genetically enhanced PGR can contribute strongly to the overall impacts and outcomes of this Plan by more effectively mobilizing NPGS PGR, their valuable traits, and associated descriptive information for more efficient adaptation of crops to rapid changes in climate and market demands, to ensure domestic and international food security, and to preserve the economic vitality of U.S. agriculture.

Implementation of the NPGS Plan

The schedule and progress for implementing the NPGS Plan depend on support by the Administration and budgetary increases appropriated by Congress. The following implementation timetable assumes that ARS can fully control how budgetary increases are applied to different PGR management priorities, crops, and NPGS genebank units. If the Plan were not fully funded, not funded according to the proposed schedule, or if funding were earmarked to specific genebank units or crops, the Plan's strategies and timetables will be adjusted accordingly.

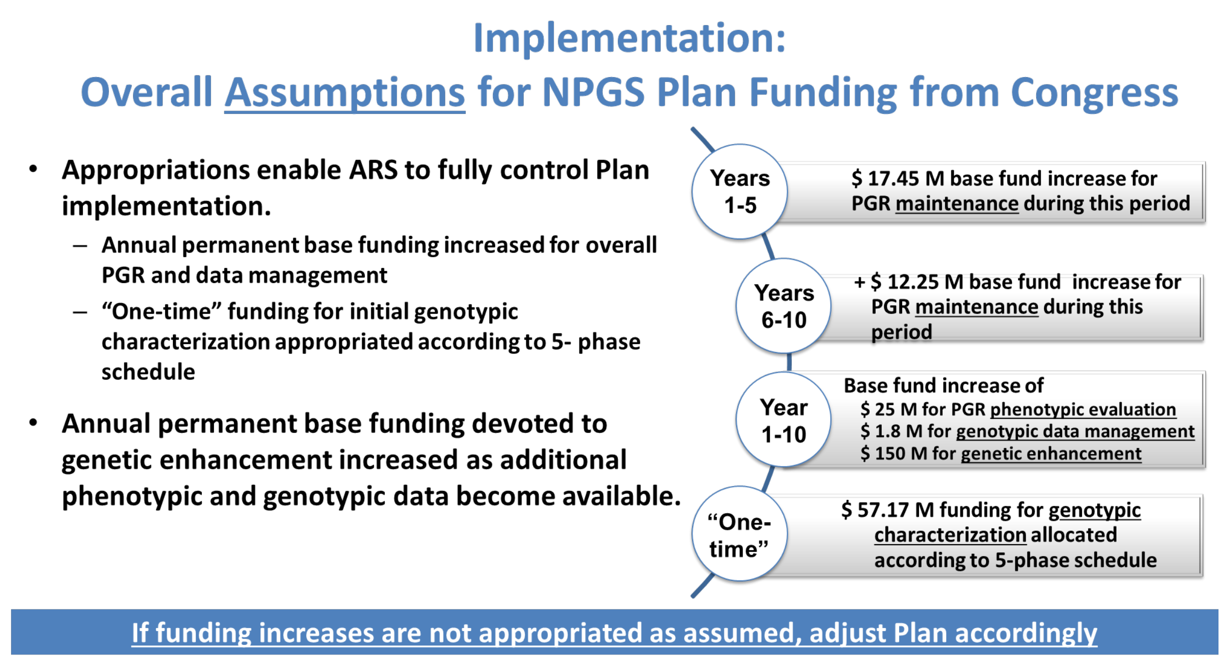



**Fig. 16** outlines how the Plan would be implemented, given overall assumptions about funding increases appropriated by Congress. *The costs to implement this plan are estimated and do not constitute a USDA request for funding.* The text at the left of the figure presents details about those assumptions. The diagram at the right of the figure outlines the proposed schedule for recurrent base funding increases and "one-time" funding (for genotypic characterizations) to support the NPGS Plan. The schedule is calibrated roughly according to 5-year intervals. If the funding is not appropriated as assumed, the schedules and priorities for the Plan would be adjusted accordingly.

Permanent increases in annual, recurrent base funding to total $17.45 million (M) are needed during the first 5 years and an additional $12.25 M for the second 5 years of the Plan to support research to develop new PGR maintenance methods and apply them to reduce and avoid PGR maintenance backlogs across all NPGS genebank units (Fig. 16, and the Technical Details document). During the 10-year Plan period, an increase in annual, recurrent base funding of $25 M is needed to develop new PGR phenotypic evaluation methods, including high-throughput phenomic approaches; and to greatly expand PGR evaluation capacities and programs with university, NGO, Tribal Nation, and private-sector collaborators. An additional increase in annual, recurrent base funding ($1.8 M) is needed to manage, analyze, and deliver the higher volumes of data generated by the expanded phenotypic evaluation and genotypic characterization programs. Genotypic characterization of the NPGS PGR accessions would be funded by a total "one-time" funding of $57.17 M during the 10-year Plan, according to the five-phase schedule (Fig. 15) described in greater depth in the Technical Details document.

If Administration and Congressional annual budget processes indicated that funding to initiate the NPGS Plan should begin in the subsequent fiscal year, the NPGS would convene meetings of USDA/ARS staff to develop and refine detailed implementation strategies for the initial stages of the Plan (Fig. 17). High-level working groups and technical steering groups composed of ARS staff would be assembled for Plan oversight, implementation, and guidance. NPGS staff, CGCs, the NGRAC, and other customers/stakeholders would be consulted to refine crop-specific priorities for PGR management and genetic enhancement.

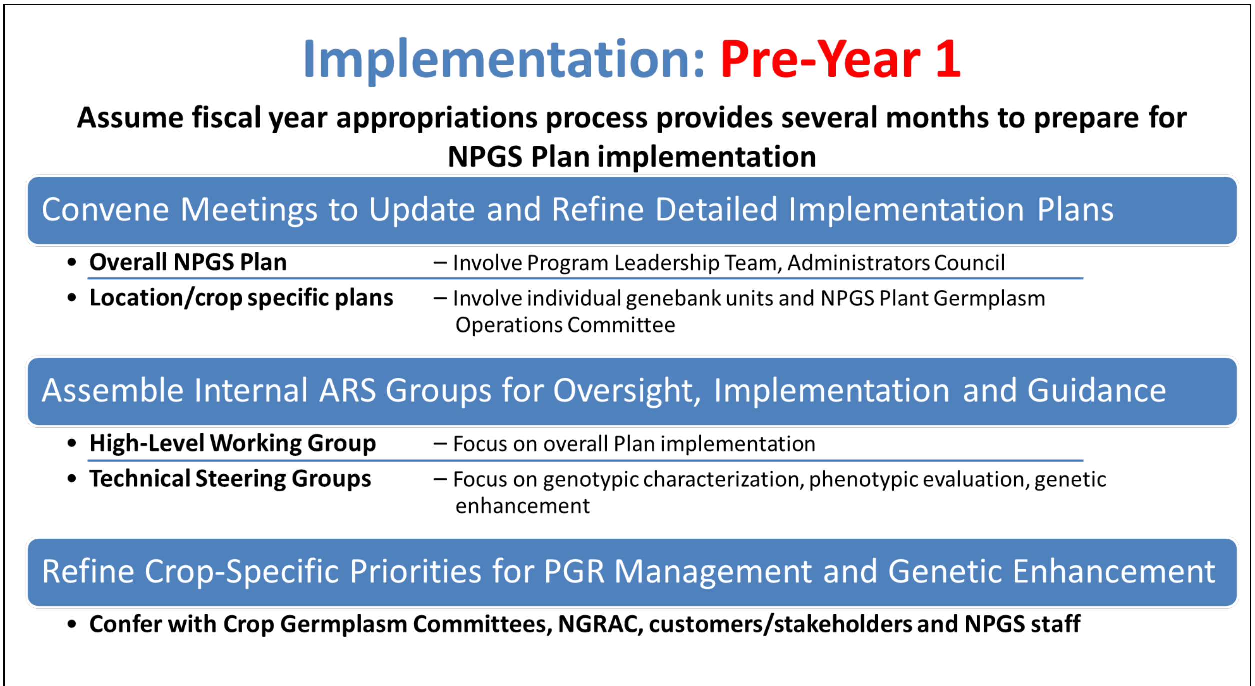



**Fig. 17** lists some of preparatory steps to be conducted preceding implementation of the NPGS Plan. Internal ARS working groups will be assembled to review and refine the Plan; develop procedures for oversight and guidance of Plan implementation; and refine crop-specific priorities for the implementing the Plan. ARS will confer extensively with the NGRAC, CGCs, other customers/stakeholders, and the NPGS staff during this key period for implementing the Plan.

During the first year of Plan funding, NPGS staff will focus on the priority outcomes of improving and expanding infrastructure, procuring needed equipment, and hiring and training additional staff (Fig. 18). NPGS staff would begin conducting research to devise optimal PGR and data management methods; establish contracts with fee-based genotyping services; and establish cooperative research agreements with university, NGO, Tribal Nation, and private-sector cooperators for methods development, genotypic characterizations, phenotypic evaluations, and initiating genetic enhancement projects (Fig. 18). During Year 2, the Plan implementation would be adjusted according to experience gained in Year 1, and based on available funding (Fig. 19).

## Implementation: Year 1

| | |
|---|---|
| **Address Infrastructural Needs** | **Line management and NPGS staff consult with Facilities Division about buildings and facilities needs, coordinate with Capital Investment Strategy** |
| | **Line management and NPGS staff consult with university hosts/landowners about availability of additional field space, lab-office space, and land for cultivation, expanded cold rooms, greenhouses and screenhouses** |
| **Resources & Personnel** | **NPGS staff procures equipment and supplies** |
| | **Staffing: Hire temporary technical personnel, students, post-docs, etc. through agreements with universities (especially 1890 & 1994 schools)**<br>**Develop permanent NPGS staff position descriptions and initiate hiring processes** |
| | **NPGS staff expand current PGR management education and training programs** |
| **Maintenance, Applied Research & Development** | **NPGS staff and cooperators initiate research on developing optimal methods for PGR and data management** |
| | **NPGS staff and ARS Office of National Programs update detailed plans for expanded PGR and data management operations in subsequent years** |
| **Characterization, Evaluation, & Genetic Enhancement** | **ARS Office of National Programs and NPGS staff establish contracts with service providers to conduct genotypic characterization** |
| | **Establish detailed implementation schedules for each NPGS site** |
| | **NPGS staff and line management establish cooperative research agreements with universities and private-sector cooperators** |

**Fig. 18** lists details for two major priorities of the NPGS Plan in Year 1 of Implementation: 1) addressing NPGS infrastructural needs; and 2) procuring equipment, supplies, and training and hiring personnel for the NPGS. Extensive consultation with building and facilities experts, customers/stakeholders, and university partners will be necessary in Year 1 of the Plan implementation.

The lower half lists details for two additional major priorities of the NPGS Plan in Year 1 of implementation: 1) beginning to conduct applied research for optimal PGR and data management methods; and 2) formulating detailed implementation schedules for beginning genotypic characterizations, phenotypic evaluations, and genetic enhancement projects. Addressing these priorities will involve establishing numerous contracts with service providers, and cooperative research agreements with universities and private-sector collaborators.

## Implementation: Year 2

**Address Infrastructural Needs**

- Ongoing consultation with Facilities Division about buildings and facilities needs, coordinated with Capital Investment Strategy
- Initiate building and facilities expansion
- Continued consultation with university hosts/landowners that secures additional field space, lab-office space, and additional land for ARS facilities expansion

**Additional Resources & Personnel**

- Continued procurement of equipment and supplies
- Staffing: Continued hiring of temporary technical staff, students, post-docs, etc. through agreements with universities (especially 1890 & 1994 schools)
  Hiring of permanent NPGS staff
- Expanded PGR management education and training programs for incoming and current NPGS employees

**Maintenance, Applied Research & Development**

- PGR and data management operations expanded according to genebank and/or crop priorities, new methods developed, and assessment of feasibilities
- Conduct pilot projects/tests of new PGR and data management approaches and methods, as they are developed
- Begin discussions with land management agencies for possible sites for in situ PGR conservation
- Begin to reduce backlogs in PGR and data management

**Characterization, Evaluation, & Genetic Enhancement**

- Expand research on developing optimal methods for PGR genotypic characterization, phenotypic evaluation, and genetic enhancement
- Initiate PGR evaluations that incorporate up to date phenomic approaches
- Implement Phases 1 and 2 of genotypic characterization for priority PGR

**Adjust Implementation of Plan based on Year 1 experience and funding**

**Fig. 19** Implementation of the two major priorities of the Plan will continue in Year 2: 1) addressing infrastructural needs; and 2) procuring equipment, supplies, and training and hiring personnel. Expansion of NPGS buildings and facilities will begin. More staff will be hired and trained, and more equipment and supplies procured. Extensive consultation with ARS building and facilities experts, customers/stakeholders, and university partners will continue. The implementation of the Plan will be adjusted according to available funding and accumulated experience from Year 1.

Implementation of the two additional major priorities of the Plan will continue in Year 2: 1) PGR and data management operations will be expanded according to information gained with initial applied research; pilot projects will be conducted; possible in situ conservation sites will be investigated; backlogs in PGR and data management within the NPGS will begin to be reduced and 2) the initial phases of the genotypic characterization projects will be conducted; phenotypic evaluations incorporating phenomic approaches will begin; and applied research to develop optimal genotypic characterization, phenotypic evaluation, and genetic enhancement methods will continue.

**Implementation: Years 3-5**

| | |
|---|---|
| Infrastructure, Personnel Needs, & Additional Resources | Many facilities, cold storage, greenhouse and screenhouse space, and fields expanded or expansion near completion |
| | Most equipment and supplies procured |
| | Most additional NPGS staff hired and trained |
| Maintenance & Applied R&D | More efficient/effective PGR management methods developed from ongoing research |
| | Expand PGR and data management operations based on research results, feasibilities, and genebank/crop priorities |
| | Reduce backlogs in PGR and data management according to Plan schedule |
| Characterization, Evaluation, & Genetic Enhancement | Genotypic characterization Phases 1 and 2 near completion for some crops. Phenotypic evaluation begins to identify valuable accessions and traits for genetic improvement. |
| | Based on characterization and evaluation data accumulated, expand genetic enhancement of PGR for priority crops, in collaboration with academic and private -sector cooperators |

**Implementation Plan adjusted based on accumulated experience, progress, funding available**

**Fig. 20** During Years 3-5, the NPGS will continue to implement the major Plan priorities of expanding infrastructure; procuring equipment and supplies; training and hiring personnel; conducting applied research for developing optimal PGR and data management methods; applying those optimal methods to reduce PGR and data management backlogs within the NPGS; completing genotypic characterizations for some crops; expanding phenotypic evaluations for priority crops; and based on the accumulated data and results from characterizations and evaluations, expanding genetic enhancement projects through cooperative research agreements with universities and private-sector collaborators.

During Years 3-5 of the Plan implementation (Fig. 20), much of the requisite additional infrastructure, equipment, and supplies should be in place, and additional NPGS staff hired and trained. Applied research should begin to deliver superior new PGR management methods, and the expanded PGR operational capacities should begin to reduce backlogs according to the Plan schedules (see the Technical Details document). The first two phases of the genotypic characterization program (see the Technical Details document) should be near completion for some crops. The expanded phenotypic evaluation program will have generated new phenomic-based approaches and begun to identify priority accessions and traits for genetic enhancement and breeding programs. The greatly expanded volumes of genotypic and phenotypic data that will be available for NPGS PGR will accelerate the progress of multi-year genetic enhancement projects for priority crops, an outcome that would especially benefit slowly-growing tree crops.

The progress of the Plan's implementation and the Plan's achievements and impacts will be formally assessed at Year 5 through internal ARS reviews, presentations at a public workshop or symposium devoted to the Plan's progress, and through formal reports to the Congress, Administration, the NGRAC, and customers and stakeholders (Fig. 21). This 5-year assessment will be in addition to ARS's regular annual reviews of research project performance. Based on the recommendations and directives received from the assessment, and technological advances, the strategies and priorities for Plan implementation will be adjusted for the second 5-year period of the Plan.

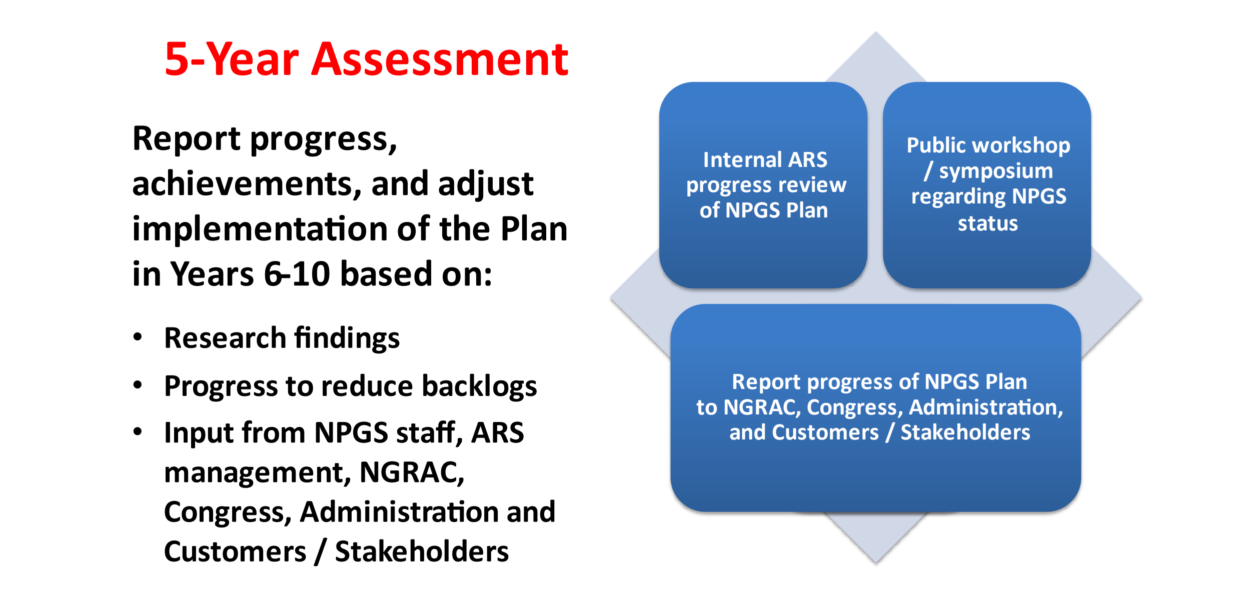



**Fig. 21** Implementation of the Plan will pause briefly in Year 5 to conduct workshops and/or symposia to report progress; review outcomes; and adjust the Plan based on lessons learned and accumulated experience. "Mid-course corrections" will take into account advances in research and technology; progress with reducing backlogs in PGR and data management; and input from the NGRAC, Congress, diverse customers/stakeholders, and from within ARS.

During Years 6-10 (Fig. 22), the NPGS infrastructural and personnel expansions should be completed, and PGR management operations should be substantially improved. Applied research should deliver the outcomes of more efficient and effective PGR management methods. Operational backlogs should be reduced or eliminated; expanded PGR management capacities will enable the NPGS to avoid future backlogs. Genotypic characterizations should be complete for 450,000 accessions of most crops; characterizing the ca. 150,000 accessions remaining in the NPGS collections, mostly certain wild species and crop wild relatives, would be addressed in future years. Phenomic approaches developed by NPGS researchers and collaborators should have the impact of generating large volumes of phenotypic evaluation data valuable for supporting and accelerating the progress of breeding and genetic enhancement programs. Multi-year, collaborative genetic enhancement programs should begin to deliver adapted populations with key traits derived from NPGS PGR, or new, genetically-divergent genepools that expand the breadth of genetic diversity immediately available to safeguard national economic and food security more broadly, and as a component of the National Plant Disease Recovery System.

Similar to the Year 5 review, the NPGS Plan will be assessed at Year 10 (Fig. 23), focusing on new progress and results. By Year 10, the NPGS should have achieved the key outcomes of more PGR, with ample associated genotypic and phenotypic data, and genetically enhanced populations or lines available for addressing rapidly changing market and environmental conditions, and evolving virulent diseases and pests. By then, more genetically-engineered or gene-edited PGR and specialized genetic stocks will require conservation and distribution from the NPGS as well. At Year 10 of the Plan, the quality and performance of NPGS operations and applied research should be well-suited to meet future challenges to crop agriculture in the United States and globally.

## Implementation: Years 6-10

| | |
|---|---|
| **Infrastructure, Personnel Needs, & Additional Resources** | Completed expansion of new facilities, cold storage, greenhouse and screenhouse space |
| | NPGS genebank units adequately equipped and supplied |
| | NPGS genebank units adequately staffed and personnel trained |
| **Maintenance & Applied R&D** | PGR and data management operations expanded sufficiently to meet demands for PGR and associated data |
| | More efficient/effective PGR management approaches developed from ongoing research |
| | Eliminated/reduced backlogs in PGR and data management according to Plan schedule |
| **Characterization, Evaluation, & Genetic Enhancement** | Genotypic characterization Phases 3 to 5 completed for accessions of most crops |
| | Phenomic approaches generate large volumes of phenotypic evaluation data for priority traits |
| | Expanded collaborative genetic enhancement programs deliver enhanced PGR for priority crops |

**Implementation Plan adjustedbased on 5-year assessment, progress, and funding available**

**Fig. 22** During Years 6-10, the Plan will continue to implement its major priorities, adjusted according to accumulated experience, progress achieved, funding available, and the results of the 5-year assessment. By the end of Year 10, infrastructural expansion for the NPGS should be complete; the needed equipment and supplies should have been procured; and NPGS genebank units should be adequately staffed with trained personnel. Applied research will have developed optimal PGR and data management methods that have been applied to reduce or eliminate PGR and data management backlogs in the NPGS. Genotypic characterizations will be complete for most crops and accessions managed by the NPGS; and phenotypic evaluations will be routinely conducted by phenomic approaches that generate large volumes of valuable data for priority crops. The expanded genetic enhancement projects, conducted through cooperative research agreements with universities and private-sector collaborators, will have begun to deliver enhanced PGR for priority crops.

## 10-Year Assessment

### Report outcomes of NPGS Plan

- Eliminated or minimized backlogs of PGR maintenance, characterization, and evaluation: more PGR and data available
- Updated and upgraded NPGS PGR management capacities and operations
- Initial achievements of expanded genetic enhancement programs for priority crops


**Fig. 23**. The Plan will end at Year 10 with workshops and/or symposia to report progress and review the Plan's outcomes. If the Plan were successfully implemented, outcomes will include elimination or minimization of backlogs in PGR management; a wealth of high-quality PGR and associated information available for research and breeding; state-of-the-art NPGS facilities, capacities, and operations; and expanded genetic enhancement programs that have or will release valuable improved PGR for U. S. and global agriculture.

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