NC007: Conservation, Management, Enhancement and Utilization of Plant Genetic Resources

Approved

(Multistate Research Project)

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Statement of Issues and Justification

The conservation, management and utilization of plant genetic resources, also known as germplasm, form the basis for harnessing genetic diversity to create and sustain agricultural production systems and a stable, nutritious national food supply. Germplasm, both the genetic material (genes, groups of genes, chromosomes) that controls heredity and the tissues, organs and organisms that express the variation contained in that genetic material, provides the essential building blocks to ensure future improvements in food, fiber and biofuel production and quality. Diverse germplasm is crucial to our ability to continually refine cultivars, inputs, production systems, markets and end-use processes to respond to production challenges and to changing societal needs, including support of a rapidly emerging bioenergy industry. Genetic resources, in combination with water, air, soil, minerals and crop management practices, together define the agricultural production system that sustains humanity and the stability of our society. These resources also comprise the essence of our environment and, consequently, our quality of life by providing crucial ecological services and valued aesthetic qualities.

As the major grain production area in the world, the vitality of the agricultural system of the North Central Region (NCR) is crucial to global food security. Historically, many of the region's crops were not indigenous to the U.S. Diverse plant genetic resources and associated information for use in crop development are vital to ensure the continued productivity of this region, given ever changing environmental and societal needs. Production of corn and non-native grain species has helped the NCR become the world's major grain production area. Therefore, the health of the agricultural system of the NCR is crucial to global food security, and increasingly also to security of energy production in the U.S. Expanded use of corn and lignocellulosic materials for ethanol production and soybean for biodiesel is now considered fundamental to U.S. security.

Interest is increasing in diversifying the array of crops that can fit into existing production systems to enhance the economic viability of producers and provide new market alternatives. Areas within the NCR utilize plant diversity to different degrees in their agricultural production, some extensively; yet abiotic, biotic and market pressures are dynamic and will continue to threaten the profitability and, therefore, the sustainability of existing crop production. Development of crops that can be integrated into sustainable agricultural production systems supports the achievement of national rural development and environmental quality objectives. Crop plants must also be evaluated for invasive potential, and appropriate risk assessments made concerning their introduction into new geographic areas.

Prior to the use of petroleum for energy production, society depended much more intimately on plant products for fuel and industrial feedstocks. The supply of petroleum, also plant-based, is finite and its cost increasingly volatile. Society is looking once again to agricultural-production solutions for its energy and industrial raw-material needs. Expanded use of corn for ethanol production, soybean, canola, camelina, and sunflower for biodiesel, and the promise of lignocellulosic feedstocks for energy production (now considered to be highly feasible) are considered fundamental to U.S. energy security. The nation's maize collection, which comprises approximately one-third of the North Central Regional Plant Introduction Station's (NCRPIS) holdings, is a key resource for future energy security as well as for food and feed.

Research and development related to the potential utilization of alternative plant species for energy production and for food, fuel, fiber, medicinal/nutriceutical, and biobased products are all increasing in priority. However, developing our understanding of selectable traits that can contribute to the above objectives is challenging.

Because water is a limiting factor for production in many areas of the globe as well as in the U.S., development of drought-tolerant varieties is an important objective. Production of crops for many purposes on marginally productive lands under current cropping systems is also increasing, including for biomass for energy; this is hoped to have a positive impact on rural development. Understanding how to manage and produce new crops is a complex task, and important in order to minimize economic and environmental risks and maximize benefits to producers, end-users and consumers. The Department of Energy is actively partnering with NCR and other researchers in plant genetics, biochemistry, germplasm conservation, agronomy and engineering to understand the energy potential of new and established crops.

By using the products of plant genome sequencing efforts, researchers can link phenotypic and genomic information and understand gene function in ways never before possible, enabling innovative uses of plant genetic resources and new impacts and benefits to society. It is said that biological discovery in the 21st century will be what biochemistry was to industrial development in the 20th century. For example, the National Institutes of Health (NIH) have supported the development of medicinal-plant collections at the NCRPIS as part of a larger, multidisciplinary botanical research center that links phytochemical profiles, genotyping, and bioactivity assays to improve our understanding of botanical dietary supplements.

Diverse germplasm collections are developed and maintained at the NCRPIS, an element of the National Plant Germplasm System (NPGS). The NCRPIS has been partially funded by Regional (now Multi-State) Project NC-7 since 1947. The function of a germplasm collection is analogous to that of a library; researchers 'borrow' its resources to develop solutions for dietary and nutritional needs, biotic and abiotic production issues, phytoremediation and rehabilitation of disturbed environments, and to provide genetic diversity used for a wide array of basic plant research objectives. Researchers return repeatedly to the 'library' as a source of allelic diversity. Shared research results increase the overall value of the library holdings for subsequent investigators who build upon previous discovery and invention. The NCRPIS was the first Regional Plant Introduction Station in the U.S., and has served as a major component of the network of 26 NPGS sites for the last 58 years. The NCRPIS provides plant genetic resources, associated information, and a wide variety of technical and leadership services devoted to substantially improving agricultural technology in the U.S. and abroad. In 2003, it was designated by the USDA-ARS as a mission-critical site.

Since 1954, the NCRPIS has coordinated a cooperative network involving the NCR's State Agricultural Experiment Stations, the USDA Natural Resources Conservation

Service, and public gardens and arboreta to conduct long-term evaluations of promising new trees and shrubs. This network collects and summarizes performance data that shed light on plant-environment interactions and provide practical advice to landscape professionals. The NCR is an especially challenging region for the cultivation of trees and shrubs, with its climatic extremes, grassland soils, and increasing urbanization. New biotic stresses caused by the rise of new pests and diseases, such as Emerald Ash Borer, Asian Longhorned Beetle, and more virulent strains of Dutch Elm Disease, present special challenges that can only be addressed by ensuring the ongoing availability of a diverse array of well-adapted landscape plants. The challenges posed to U.S. agricultural productivity, the nature of the demand to meet these challenges, and issues involved have been well-summarized (34); pests and plant diseases are estimated to cause losses of $20-33 billion annually, and recent trends increase risks due to new or changing pests and their geographic distributions. The role of safeguarding the world's crop diversity collections should belong to governments, international organizations, and the private sector acting in partnership for the public good.

Because of the diversity of environments and needs in the NCR, and the diversity of research interests and expertise available, it is only logical and fitting that a multi-disciplinary effort utilizing the talents of all interested researchers be rigorously applied to develop and test potential solutions to these many challenges.

The impacts of successful germplasm conservation, management, enhancement and utilization can be measured in the introduction of economically viable new crops and cultivars and new uses for existing crops based on a thorough understanding of their traits and properties, including nutritional, chemical, pharmaceutical, industrial and aesthetic applications. Impact is also made via contributions to our fundamental understanding of the nature and biology of genetic diversity, how it interacts with and is influenced by environment, and the resulting discoveries, inventions and applications which benefit society.

Related, Current and Previous Work

The Ames, IA NCRPIS germplasm conservation and management team includes seven federal and four state scientists, an Information Technology Specialist and technical team members who effectively collaborate to achieve mission objectives and goals. Technical and administrative support by seven state and fourteen federal employees provides expertise and infrastructure for farm operations, viability testing, seed processing, greenhouse and facility management, laboratory, information management and analytical support. The team conserves germplasm and associated information and conducts research on the campus of Iowa State University in Ames, IA and at the nearby NCRPIS farm and headquarters facilities located on land owned by the Iowa State Agricultural Experiment Station. (Appendix Figure 1 provides organizational and staffing information.)

Each of the six curatorial teams interacts with the Program Manager, Research Plant Pathologist, Entomologist and Agronomist. Staff members work in cross-project teams, determined by their expertise and interests, to address issues that affect multiple curatorial or support teams, including: pollinator insect efficacy and management; detection, quantification and elimination of seed borne pathogens and pests; digital imaging standards and automation; georeferencing; enhancement of the internal and external (public) aspects of the Germplasm Resource Information Network (GRIN) database; development of software applications to improve quality and efficiency of data collection; and a wide range of operational and equipment innovations, which contribute to the quality of the germplasm accessions and associated information.

Reliable passport and provenance information, coupled with accurate taxonomic

identification, are fundamental to the relevance of plant genetic resources (PGR) to specific research applications. Phenotypic and genotypic characterization and evaluation data greatly increase the value of the collections for research, allowing researchers to discriminate between elements of the collection and devote their resources to those most likely to fulfill their objectives. Large numbers of germplasm samples distributed to developing countries contribute to utilization in crop breeding programs, and the secondary benefits brought about through sharing this germplasm with other scientists (36). Future demand is expected to increase, especially among scientists in developing countries.

The curatorial teams interact and collaborate with researchers at the National Center for Genetic Resource Preservation (NCGRP) at Ft. Collins, CO, the NPGS site for long-term seed storage which backs up the germplasm collections and conducts research related to germplasm viability and preservation of genetic profiles. These backup samples are held at -18 C or under liquid nitrogen (LN, vapor phase). At the NCRPIS, original samples are stored at -18 C separate from the distribution samples (or active collection) which are held at 4 C and 28% relative humidity (RH).

Collaborations between NCRPIS staff and the Database Management Unit (DBMU), which administers the GRIN database in Beltsville, MD, are extensive. Curatorial staff members regularly collaborate to exchange information and technological improvements with many other NPGS curators with whom they share many common objectives and goals, including germplasm exploration, regeneration, and characterization.

NCRPIS curators and other scientists participate with researchers in the NCR to address crop development and improvement, invasive-species risk assessment, genetic enhancement, phytosanitary health issues, pollinator-biology questions, and many other objectives. As of October 31, 2006, NCRPIS curators are responsible for 48,493 accessions of 1,862 taxa of 1,627 distinct plant species representing 326 genera, which serve as a rich resource to support the objectives of researchers in the NCR, the rest of the US, and beyond. The NCRPIS specializes in the conservation and management of a diverse array of outcrossing, heterogeneous species (summarized in Figure 1), which require facilities and methodologies for controlled pollination. The project acquires, documents, conserves, maintains, freely distributes and enhances germplasm of agronomic and horticultural crops valued for food, feed, energy, industrial, landscape, and medicinal and/or nutriceutical purposes, and encourages their use in research and crop development.

The activities of the researchers who utilize PGR provide new sources of varieties with improved performance for yield, pest or abiotic stress resistance, contribute to human or animal health and nutrition, aesthetic value, and provide value to consumers, producers and end users. Germplasm requests come from researchers in both the private and public sectors concerned with applied and basic research applications, educators, historians, and members of the public interested in their use for improving their quality of life and health.

Every state in the NCR conducts germplasm research connected with Multi-State Research Project NC-7. A search of the CSREES and ARS CRIS systems for projects involving Plant Genetic Resources resulted in identification of 122 projects in the NCR, and 564 Projects in the U.S. (Table 1).

On average, NCR researchers annually receive from the NPGS ca. 43% of its domestic germplasm distributions or 27% of total distributions (Appendix Table 1). More specifically, ca. 25% of all germplasm distributions from the NCRPIS are directed to NCR researchers (Appendix Table 2). Distributions from the NCRPIS have accounted for ca. 15% of all NPGS distributions for the past seven years (Appendix Table 2), although NCRPIS holdings make up only 10% of the NPGS collections, reflecting the

overall importance of these holdings to agricultural research. The demand for PGR from all NPGS collections, although varying from year to year, remains high (Appendix Table 3). Demand for, and use of the resources, have been documented (16,46).

Projects that benefit from NPGS germplasm collections include Brassica research by NCR scientists in KS, NE, ND and SD (including Regional Technical Advisory Committee (RTAC) members Burton Johnson (ND); David Baltensperger (NE), Mike Stamm (KS), and Karl Glover (SD), amaranth and millet research by former RTAC member David Baltensberger (NE) (2, 3, 37, 11); forage research by former RTAC member Charlie Brummer (IA); agronomic research necessary for successful production and commercialization by RTAC member Burton Johnson (ND) (4, 5, 6, 18, 21); forestry research by current RTAC member Richard Hall (IA); fruit research by RTAC members Amy Iezzoni (MI) and Jules Janick (IN), vegetable research by RTAC member David Francis (OH) and WI researchers; maize research by RTAC member William Tracy (WI) and many other maize scientists; and ornamental research by former RTAC member Stan Hokanson (MN). Soybean germplasm is utilized by researchers in at least five NCR states; an outstanding contribution by RTAC member Ted Hymowitz (IL) identified 12 germplasm sources of soybean, wild annual and wild perennial Glycine sp. which did not produce proteins responsible for human allergenicity while screening 12,266 accessions (22).

The perspectives contributed by RTAC members, with their diverse experiences and research interests, are invaluable to developing an understanding of germplasm's potential and value throughout the NPGS. Specific information about the RTAC's function and organization is provided in the Methods and Organization / Governance sections below. Other oilseed crops research (rapeseed and sunflower) is conducted primarily in KS, SD, ND, NE, and WI; all states actively conduct research on new crops. Iowa researchers are part of a research effort funded by the NIH to establish well-documented and characterized collections of Echinacea and Hypericum and elucidate the basis of their phytopharmaceutical activity.

The NC7 Ornamental Trials are the longest running ornamental evaluation trials in the US, entering their 53rd year in 2007. Focused on evaluating woody ornamental introductions for their adaptation to the NCR, aesthetic and productive qualities, NCR trial cooperators have identified important sources of ornamental germplasm for the horticultural industry (43). Eight NCR states have CRIS Projects connected with the NC7 Ornamental Trials. Because of the successes that germplasm introductions have brought to the horticultural industry in the U.S., a new genebank for herbaceous ornamentals, the Ornamental Plant Germplasm Center (OPGC) was established at the Ohio State University (39). NCRPIS personnel have worked closely with those of the new OPGC to transfer technology, training, and methodology for germplasm management, as well as germplasm itself, to enable OPGC personnel to quickly become adept in genebank management functions.

Objectives

1. Cooperate and participate as a key element in the NPGS, a coordinated national acquisition and management program of plant germplasm valued for agricultural, horticultural, environmental, medicinal and industrial uses in the NCR and through the U.S.
2. Conserve seed and/or vegetative stock of more than 1700 plant species.
3. Within the NCR, throughout the U.S., and internationally, encourage the use of a broad diversity of germplasm to reduce crop genetic vulnerability. Provide resources, information and expertise that foster the development of new crops and new uses for existing crops, and facilitate cultivar improvement of established crops, thus contributing to a sustainable, biobased economy.
4. Contribute to understanding of plant-environment interactions, including risk assessment and communication of characteristics that would differentiate a

species' ability to adapt and whether it can become invasive in specific environments.
5. Educate students, scientists and the general public regarding plant germplasm resource issues.
6. Conduct research, and develop an institutional infrastructure needed to attain the preceding objectives efficiently and effectively, including advancements in software applications development to improve functions and efficiencies.

Methods

The Multi-State Research Projects support four Regional Plant Introduction Stations, including the NCRPIS through the NC-7 Project, and help sustain major components of our national effort to provide germplasm and information for basic and applied research. Because needs are continual for new and improved crops and for basic scientific research, the NC-7 Project is, by nature, a long-term effort. Changes in its organization and mission generally evolve gradually, but specific management procedures can change dramatically in response to the development of new technologies and research findings. With continuing NC-7 support, the NCRPIS will continue to be the leading NPGS active site for managing heterozygous, heterogeneous, seed-propagated germplasm that generally requires controlled pollination, and for managing the requisite insect pollinators.

A unique federal, state, and private-sector cooperation has been essential to the effectiveness of the NC-7 Project and is critical to its future success. NC-7 funds provided approximately 20-25% of the project's monetary budget, not including ISU's substantial in-kind support, for the period 2001-2006, supporting up to 12 permanent state employees including three curators and their support staff, the Program Manager and farm and facility support staff, necessary equipment, travel and operating costs. These critically needed funds have resulted from a long-standing commitment from the SAES Directors of the NCR's land grant universities, who have provided funding taken 'off-the-top' of the Multi-State Research Funds (MRF) received from the USDA/ARS Cooperative State Research, Education, and Extension Service (CSREES).

The USDA/ARS provides 75-80% of the NCRPIS budget (see Appendix Tables 4 and 5 for budget history), including funds for salaries of many of the staff, general operations, and certain facilities and equipment.

The State of Iowa, through the Iowa Agriculture and Home Economics Experiment Station at Iowa State University, provides substantial in-kind and fiscal support in the form of land (120 acres), facilities, benefits and administrative services for ISU employees supported by regional funds, and other local assistance.

Many other researchers and institutions in the U.S. actively manage germplasm as a component of their ongoing activities, but none has the total 'system' approach of the NPGS. The NCRPIS demonstrates that fact particularly well. During the past 57 years, the NPGS and the NCRPIS in particular have built a coordinated structure and critical mass of trained curatorial and support staff, unparalleled within the United States. Individual states and the private sector lack such infrastructure and broad expertise. Some of the NPGSs major components are described in Appendix Figure 2.

Objective 1: NCRPIS will acquire and manage key germplasm and associated information needed to support agricultural, horticultural, environmental, medicinal and industrial uses. NCRPIS staff and NC7 participants engage in and support plant exploration, and manage the associated passport and descriptive information. CGC members contribute to the development of acquisition priorities and exploration or exchange plans, with other PGR preservation institutions. NCRPIS maintains an extensive global network of seed exchange relations, including seed savers' exchanges. International explorations include scientists from the respective donor

countries, who provide technical expertise critical to acquisition objectives, and valuable logistical and administrative support. A review of the 1999 Ukraine expedition describes the general process and some specific results (51). The USDA-ARS funds about 15 international and domestic plant explorations annually, designed to fill collection gaps identified by the crop curators and the 40 CGCs; germplasm and non-monetary benefits are shared with host countries (52). Iezzoni's review (20) of cherry germplasm acquisition strategy and implementation, and subsequent trait utilization from eastern and central European acquisitions details the determination of breeders to improve crops despite restrictive government policies and great personal risks. Traits targeted for germplasm acquisition are as varied as the crops themselves; in the case of garlic, routine production of garlic seed was unknown, hindering classical approaches to garlic improvement through plant breeding. Garlic from Central Asia was targeted as a source of genetic diversity for potential to improve seed production (17). Extensive collection of Allium from Central Asia supported research that has broadened taxonomic understanding of the genus, provided allelic variation for agricultural production, and yielded useful traits including male sterility, bulbing response, and disease resistance (35).

In order to develop and prioritize future medicinal plant acquisition strategies, a NCRPIS team developed a public database (27) of NPGS plant germplasm, extracted from the GRIN database, that can contribute to medicinal and/or nutriceutical research applications. In the past 5 years, NCRPIS curators participated in 11 plant collecting trips, acquiring nearly 3,080 accessions. Availability has not increased due to the transfer of available accessions to other sites, such as the relatively new OPGC in Columbus, OH (Appendix Table 7). Additional explorations are planned for medicinal, ornamental, and oilseed accessions.

Acquisition strategies are similar to a candidate gene selection approach in that select species, potential local exposure to pests, pathogens, and abiotic stresses, and sites most appropriate for research applications are targeted and resources applied accordingly. Use of modern Geographic Information System (GIS) tools, coupled with analysis of collection gaps for key taxa and regions, are used to support sound collection development strategies (19). Geopolitical events and national policies and laws can greatly inhibit free and open germplasm access and exchange; the highest acquisition priorities are not necessarily achievable at any given time (52). The efforts of the Plant Exchange Office are essential to ensuring successful expedition outcomes, and to the conservation and availability of unencumbered, freely accessible, well-documented PGR.

Objective 2: NCRPIS will continue to conserve seed and/or vegetative stock and associated information for more than 1600 plant species. Regeneration and maintenance of the working species collections is required to increase both the proportion of the collections available to researchers and those backed up in long-term security storage at the NCGRP. From 2000-2006, over 29,300 accessions were tested for viability, and over 11,000 grown for regeneration (Appendix Table 7). Approximately 66% of the collections are available, despite substantial regeneration efforts. This is due primarily to: 1) high demand for our holdings, particularly maize, resulting in annual distribution of 20-25% of our holdings; 2) ongoing germplasm acquisition; and 3) transfer of some highly available crop species to other sites during the past five years. Unavailable accessions represent a combination of those that can be: 1) easily regenerated in Ames, 2) regenerated in Ames in greenhouse environments equipped to support special growth requirements, and also support the need to verify identity and prevent introduction of potentially invasive accessions, 3) grown in other U.S. environments which can support regenerations needs, including tropical winter nursery sites, or 4) grown only in known select international environments, or habitats. Curators face challenging and time-consuming processes in order to distinguish among these categories and determine appropriate regeneration

strategies for materials that have not been grown or for which previous regeneration attempts were unsuccessful. Some unavailable accessions may not be viable, are duplicates, or have extremely small sample sizes.

Regeneration activities are conducted in fields in Ames and at carefully selected collaborator sites, in greenhouses, and growth chambers (e.g., spinach is regenerated in positive pressure chambers in the USDA/ARS facility at Salinas, CA). Specific protocols are developed based on species biology, photoperiod and vernalization requirements, and the need to produce high-quality seeds that preserve genetic integrity, and are documented in the NCRPIS Operations Manual. Taxonomic identity is verified, genetic purity standards maintained, and phytosanitary precautions are implemented to guard against distribution of pathogens.

A wide range of pollination-control methods are utilized and refined to preserve the genetic integrity of diverse PGR. Accessions of maize and its relatives are increased using standard hand-pollination and isolation procedures which preclude fertilization by foreign pollen. Species, such as cucumbers, melons, squashes, brassicas, carrots and other insect-pollinated taxa are caged and bee- or fly-pollinated. Sunflower accessions are pollinated by hand or in screen cages with insect pollinators to preclude pollen contamination. Other largely self-pollinating species (e.g., millets) are open-pollinated in the field but caged to reduce bird predation, or grown in plastic tents in greenhouses (e.g., Amaranthus). Applied research efforts over the past five years have optimized use of non-stinging pollinators, such as the alfalfa leaf cutter bee (Megachile rotundata) and mason bee (Osmia cornifrons). Use of these insects provides for increased worker safety and financial savings compared to honeybees (Apis mellifera). References useful in assessing contribution in this area include 1, 12, 14, 45, 53-56.

Viability methods development is also important to achieving this objective. Improvements to protocols for storing and germinating seed Cuphea seeds (48) have resulted from collaborations between NCRPIS and NCGRP personnel to determine seed storage physiology and optimum conditions for Cuphea (13). C. carthagenensis (Jacq.) seeds retained high viability when stored at 25 C, but quickly lost viability when stored at 5 C. A 45 C treatment before imbibition restored germination of dry seeds by melting the crystallized triacylglycerols which were in solid phase at 5 C. Further studies revealed that that transition from the anhydrobiotic to a hydrated state, which occurs during early imbibition of seeds, is lethal if lipid reserves are crystalline when seeds are imbibed briefly (41). Additional research is needed to understand optimum storage conditions and viability protocols for many species.

Objective 3: The NC-7 Project, through NCRPIS staff and participants, will encourage use of genetic diversity to reduce crop genetic vulnerability (see Outreach Section). Significant improvements achieved in our information-management infrastructure over the past decade, coupled with improved capabilities of the GRIN database, enable linkage of information from many sources to the collections in novel ways, such as through the genomics databases. We will: 1) invest in training to enable staff to utilize information effectively and efficiently, and deliver quality, useful data and recommendations in a concise and useable format to requesting researchers, 2) expand efforts to acquire evaluation and descriptive information from our own and collaborative investigations will expand, 3) integrate information capture with our ongoing regeneration processes, and 4) partner with SAES and other researchers to address challenges associated with genetic characterization of heterogeneous PGR while limiting assignment of scarce NCRPIS-assigned resources, based on our RTAC's counsel.

Appendix Table 7 illustrates the evaluation and characterization efforts for 2001-2006; over 107,000 observations were added on nearly 39,500 accessions to the GRIN database. NIR information available on maize quality traits has generated new interest in and opportunities for research and development. Disease resistance evaluations,

such as that of the cucumber collection for powdery mildew resistance (8), provide valuable data used to target PGR for crop improvement. Molecular marker and other genetic characterization information are critical for developing a better understanding of the relationships of accessions among and within species, assessing genetic profiles, determining measures of diversity and evolutionary divergence, understanding where duplication exists, and providing sequence and marker information that can be associated with gene function and expression. Information availability positively impacts our ability to manage PGR effectively, as demands for funding increase disproportionately to availability. Collaborative research has resulted in genetic characterization of Echinacea (49), B. napus (15), and Coriandrum (25); we will continue to partner to develop and acquire molecular-genetic information on key collections, particularly for maize and sunflower. NCRPIS and other NPGS personnel are involved in the DBMU's efforts to ensure that GRIN will support interoperability with public genome databases, and to develop standards and protocols for genetic information entry.

Curators survey literature to determine those species and populations for which novel properties, characteristics or applications have been identified and consult with relevant CGCs to develop priorities for, and participate in, characterization and evaluation activities. This information is crucial to acquisition and management of accessions best able to contribute to research and development activities that sustain and/or enhance our economy. Identification of species of value for medicinal or nutriceutical needs is done in consultation with researchers and commercial experts to ensure that efforts are well focused.

Incorporation of the Germplasm Enhancement of Maize (GEM) CRIS Project into NCRPIS brought opportunities and focus to our maize evaluation, enhancement and utilization efforts for realizing the value of maize landraces. The GEM Project is funded by a separate CRIS; since 2003, its activities have been gradually integrated into NCRPIS operations. GEM's evaluation and enhancement efforts involving a network of over 40 private and public collaborators have resulted in release of 135 diverse lines to date, and continue to work towards realizing the maize collection's potential (6b).

In 2005, two multiple disease-resistant sunflower populations were released with resistance to three fungal leaf diseases (7). Germplasm releases of ornamental amaranth varieties from IA (9), niger, proso millet and grain amaranth varieties from NE (2, 3), Camelina from MT (33), canola from KS (38), Arugula from IN (29, 30) and numerous publications which have supported development of effective production practices (4-6, 18, 21, 32, 37) illustrate recent NC-7 Project enhancement successes. PGR high in Omega-3 fatty acids are of interest as functional foods to improve human health (10). Work to expand collections of medicinal plants and provide these materials for phytopharmaceutical/medicinal research applications provides economic opportunities for growers, while conserving native populations (e.g., black cohosh) from wild-crafting practices which decimate native stands to supply markets (26). Uses and objectives are far-ranging, as illustrated by use of wild Brassica relatives to study the effectiveness of plant defenses against herbivores (24).

Objective 4: NCRPIS will build upon past efforts to contribute to the understanding of plant-environment interactions. Understanding adaptation and the genetic trait linkages which impact adaptation are important in utilizing unadapted germplasm. One of the best developed, long-term evaluation networks for testing woody plant adaptation in North America is the NC-7 Trials network. Much of the work is conducted by SAES personnel. Data from these evaluations are useful in matching landscape plants with appropriate sites, inform us about climatic and edaphic factors that influence woody plant adaptation, and influence future acquisition and testing foci. An example is the development of the 1999 Ukraine exploration expedition and the ongoing evaluation of resulting collections (43, 51).

Knowledge of genetic, climatic, and edaphic factors and their interactions influencing plant adaptation in the NCR is valuable for use in assessing risk of invasiveness of non-native species, and is used to develop predictive environmental analogs (42, 47) and as part of more comprehensive risk-assessment models that integrate both biological attributes and geographic information (50) to predict the likelihood that non-native woody plants will naturalize. This knowledge is increasingly important in light of the rise of new pests and diseases which afflict US forests and both urban and rural landscapes, and the growing number of commercial introductions of new landscape plants (44).

Woody species adapt to their biotic and abiotic environments; deciduous leaf drop is thought to be an adaptation to temporal unavailability of water, and to snow and ice loading. Research on the relationship between leaf retention through winter and herbivore loads of two woody species that show considerable variability in deciduousness, Quercus lobata and Ceanothus velutinus, showed that leaf retention was associated with higher herbivore populations and higher levels of leaf damage in the following spring (23).

Knowledge of plant-environment interactions is extremely helpful in determining the best sites for regeneration and management of elements of our collections, and the choice of specific regeneration techniques, such as seedling vernalization. We must determine and increase regeneration capacity in suitable environments; the partnership with the NPGS regeneration site at Parlier, CA to identify species and accessions which can effectively be regenerated there, but not in Ames, is an example. Regenerations of Helianthus accessions native to the Southwestern U.S., and those adapted to a more Mediterranean climate, have proved successful in Parlier. Private and public cooperators have assisted with regeneration of Daucus, Spinacia and maize in key environments not found at NCRPIS.

Objective 5: NCRPIS staff and NC7 RTAC members will educate students, scientists and the general public regarding plant germplasm resource issues (see Outreach Section).

Objective 6: NCRPIS personnel conduct research and develop institutional infrastructure needed to attain the preceding objectives efficiently and effectively, including advancements in software application development to improve functionality and efficiency. Improvements to seed drying and processing, viability-testing methods and capacities will continue. Use of a new thermal gradient table will facilitate development of viability testing protocols for many taxa which lack such standardized methods. Research and development of real-time immuno-magnetic capture PCR, and quantitative ELISA analytical methods (28) are targeted to improve our ability to detect plant pathogens, particularly those that are seed-borne, in order to support production and distribution of healthy plants and plant propagules (31).

Completion of a software application to automate the capture and transfer of digital images to the GRIN database has recently enabled transfer of thousands of images to GRIN. As a result, over 7,400 digital images associated with accessions were loaded to GRIN in the past two years from Ames alone (Appendix Table 7); this application has been made available to the entire NPGS. Four application development projects are in progress (described in the Milestones Section). By communicating effectively with other NPGS sites to determine similar needs and investing approximately 10% extra effort in the development phase, most applications can be transferred to other NPGS sites resulting in system-wide productivity and efficiency gains.

Measurement of Progress and Results

Outputs:

- Plant explorations and exchanges will continue to address taxonomic gaps and provide needed representation in collections of crop species and their relatives and serve as a source of new collections for research and crop improvement, supporting agricultural success.
- Seed and plant viability will be monitored to ensure collection health. Methods and protocols will be developed as needed.
- Analytical and diagnostic methods to detect plant pathogens will be developed and deployed to ensure the health of plants being regenerated, and that healthy plant propagules are distributed.
- Regenerations will continue to focus on providing researchers with a diverse array of plant genetic resources, true to their original genetic profile, as a source of genes and gene products. NCRPIS has steadily increased the number of accessions available to researchers, with 66% of the collection available compared to 64% in 2000, despite a net gain of nearly 3,080 accessions and the transfer of more than 500 ornamental accessions to the OPGC and other NPGS sites. Regeneration backlogs are an obstacle to increasing evaluation and characterization efforts that provide valuable information about the collections, and are limited by greenhouse facilities. Many CGCs cite availability as a primary limitation to evaluation and characterization efforts (40).
- Insect-pollinator research will continue to be an important focus, providing needed resources for curatorial program success, and contributing to improved worker safety.
- Phenotypic, phenological and genetic characterization (sunflower and maize) and evaluation information will be made available to researchers to facilitate their objectives and provide for well-targeted use of PGR. Requestors frequent express the need for more evaluation information, especially related to maturity and adaptation, followed by biotic and abiotic stress resistance, to better target their efforts. Addition of standardized descriptors for many crops will enable more information to be made available.
- Software applications will be developed and deployed which will increase the productivity and efficiency of the NCRPIS, and be provided to other elements of the NPGS for their use. The focus of automated Accession Performance Reporting (APR) application development is to facilitate capture of information and results from research users of the germplasm, add these data to GRIN or other appropriate databases, further increasing the probability of realizing their potential value and assessing impacts from their use. Paper versions of the APR were used to assess user satisfaction with the germplasm they have been provided, and develop a sense of how various types of research needs are being met, but do not support analysis and interpretation needs.
- Distributions of plant germplasm will support the researchers of the NCR, the U.S., and internationally.
- The proportion of the collection backed up at NCGRP increased to 78% over 72% in 2000 (Table 2 and Appendix Table 6). Progress is due partially to the application of new technologies which enable us to extend our resources and equipment for regeneration, improvements in viability-testing facilities and methodologies and in monitoring, detecting and treating plant pathogens and insect pests.

Outcomes or projected Impacts:

- As demand for plant genetic resources for research use increases, the positive impacts of their use will also increase. Availability of well-documented, well-characterized, unencumbered PGR of known provenance is a key component contributing to increasing biological knowledge, agricultural success, a biobased economy, and improved health and well-being. As new evaluation and characterization information is made available, the value of PGR increases, and interest in their use increases (16). As we interact with researchers, CGCs and

other crop research experts, we try to exchange information that helps us better anticipate future challenges and research needs
- Providing PGR to educators for classroom purposes provides a useful service and raises awareness of students and the general public to the importance of PGR and their impact on daily life.
- Activities related to acquisition, documentation, characterization, maintenance, evaluation, documentation and distribution of PGR are ongoing. Given sufficient resources and reasonable growth in accession numbers, we expect that the collection will be 75% available and 85% backed up within five years, and 90% backed up within ten years.
- Genetic characterization and trait evaluations will support use of germplasm in functional genomic research and contribute to understanding the nature of biological diversity.
- Development of risk-assessment models which predict potential invasiveness of introduced species will support informed decisions relative to introduction of new plant species to the U.S.
- Software application development will support continued gains in productivity, efficiency, and information capture. As information needs increase, research activities and technologies directed towards meeting, managing and integrating tools to enable powerful insights and practical solutions are of high value.
- Release of new varieties and new knowledge from research programs using PGR will facilitate sustainable agricultural productivity and economic security.
- Use of plant genetic resources in research and Germplasm distributions will continue to support agronomic, genetic, molecular biology, plant pathology, entomological, horticultural, ecological, biochemical, industrial, anthropological, medical and pharmaceutical, animal nutrition, and bioenergy research. Their use will continue to contribute to the aesthetics and the sustainable management of the world we live in, and the health, welfare and security of the worlds peoples.

Milestones:

(2008): 1) Medicinal plant germplasm acquisition from the Republic of Georgia. 2) Development of a proposal for genetic characterization of the Helianthus collections. 3) Implementation of a software application on handheld PCs to facilitate pollinator insect delivery and management, and add comprehensive data to GRIN. 4) Development of a web-interface to enable NC-7 ornamental trial collaborators to transfer evaluation data via the web. 5) Publication of real-time immuno-magnetic capture PCR and quantitative ELISA analytical methods for seed-borne plant pathogens. 6) Distribution of the collections to researchers and educators is expected to comprise 20-25% of the holdings each and every year.

(2009): Development and implementation of an Accession Performance Reporting (APR) system to track impact from germplasm distributions, in collaboration with the DBMU which administers the GRIN database. 2) Identification of environments and collaborators to support the regeneration of tropical highland maize.

(2010): Development of applications and protocols for the capture of morphometric data from images. 2) Genetic characterization of the Helianthus collection.

(2011): Assessment of implemented APR system.

(2012): Collections may have grown by an estimated 1% annually, to reach approximately 53,000 accessions. Given continued support, the collections should be approximately 75% available and 85% backed up.

(2012): During 2007-2012, we will use the NC7 Review Process and internal benchmarks and accountability systems annually and integrate the information used to

assess our progress and better meet future needs. Our NCRPIS Operations Manual will be updated to reflect changes resulting from these processes. Specifically, we will use the following vehicles to assess progress and report results: 1) ongoing ARS Program 301 OSQR Review and CSREES Project Review & Renewal processes; 2) working with 11 CGC's to update crop status reports for NPGS; 3) annual meetings and on-going discussions with the NC-7 RTAC to report on progress, develop better understanding of ongoing research and development needs to which our curators and scientists can significantly contribute, and to seek guidance in planning future activities and directions; 4) annual AD-421 reports for both ARS and CSREES made readily available through our website; 5) station annual reports posted to our website, http://www.ars.usda.gov/main/site_main.htm?modecode=36-25-12-00; 6) specialized computer applications for electronically capturing information from APRs to better measure progress, results and impacts.

(2017): Collection size is anticipated to be approximately 58,000 accessions; availability and back-up should approach 90%.

Projected Participation

Include a completed Appendix E

Outreach Plan

The NC-7 Project, through NCRPIS staff and RTAC members, will encourage use of genetic diversity to reduce crop genetic vulnerability. The NC-7 RTAC members and participating SAES scientists can play an important role in raising awareness of the availability and potential benefits to be derived from use of plant genetic resources. These individuals, by participating in professional societies and special events in either their home institutions or beyond, through presentations and professional or popular press communications, are ultimately a source of information and research findings that provide the impetus for further investigation and applications. NCRPIS, through characterization and evaluation activities, will continue to provide information to enhance the value and utility of its collections. Significant improvements have been achieved in our information-management infrastructure over the past decade, with improvements in the capabilities of the GRIN database and enhanced abilities to link information from many sources to the collections in novel ways. In the future, connections to the genomics databases will facilitate utilization of PGR. Information pertaining to their collections is available to curators, to the broader research community, and the general public through web-access to GRIN. The amount of available information has increased greatly since the last revision and is expected to continue to increase substantially during the next ten years.

We take advantage of outreach opportunities to present germplasm resource issues and accomplishments to the public, including primary, secondary, and collegiate classes and through involvement with post-graduate education. Information, analyses and interpretations are also presented via written publications, posters and oral presentations targeted for scientific, industry, and popular audiences. In response to the 2001 NCRPIS review recommendation to increase recognition for the scholarly contributions of curators to researchers' efforts, curators have requested co-authorship of manuscripts resulting from their contributions, when appropriate, and to promote understanding of what the NPGS provides. Because of our close physical and intellectual associations with Iowa State University, we frequently provide tours and lectures for ISU students and visitors from other institutions, such as the Univ. of MN plant breeding students, the Carrot Congress, the North American Prairie Conference, etc.

In addition to these efforts, the NCRPIS conducts tours and readily explains its work to

some 400-800 individuals each year ranging from second grade students to senior national and international officials responsible for the health and vitality of their nation's agricultural systems, and meeting forums for such groups as the Iowa Honey Producers, the International Commission on Plant-Bee Relationships, etc. We advise graduate students, offer internships and participate in collaborative research partnerships.

Organization/Governance

The NC-7 Regional Technical Committee is made up of a representative from each of the Agricultural Experiment Stations of the North Central Region, along with ex-officio representatives from the USDA-ARS National Center for Agricultural Utilization Research, the USDA-ARS National Center for Genetic Resources Preservation, the NPGS Plant Exchange Office, and ARS and CSREES National Program Leaders, and the ARS Midwest Area Director. The Dean of Iowa State University's College of Agriculture currently serves as the Administrative Advisor, and the Research Leader of NCRPIS serves as the NC-7 Project Coordinator. RTAC officers include a chair, secretary, and a past-chair. The secretary typically is elected to a one-year term and becomes the chair the following year. Each year, NCRPIS staff members report results and progress, discuss issues and receive guidance from the RTAC. The project curators also report to and participate in meetings with each of the 11 pertinent Crop Germplasm Committees (Maize, New Crops, Root and Bulb Vegetable, Leafy Vegetables, Woody Landscape Plants, Herbaceous Ornamentals, Crucifer, Clover and Special Purpose Legumes, Turf and Forage Grass, Cucurbit, and Sunflower) which provide crop-specific expertise to the NPGS.

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Attachments

[Appendix Figure 1.doc] [Appendix Figure 2.doc] [Appendix Tables 1-7.doc] [Figure 1.doc] [Tables 1 and 2.doc]

Land Grant Participating States/Institutions

CA-D, CTS, DE, IL, IN, IA, KS, MI, MN, MO, NE, NJ, NYC, ND, OH, SD, TX, WI

Non Land Grant Participating States/Institutions

Signatures:

s:/Wendy Wintersteen