NRSP_TEMP006: The US Potato Genebank: Acquisition, Classification, Preservation, Evaluation and Distribution of Potato (Solanum) Germplasm

Duration:	October 2015 to September 30, 2020
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Statement of Issues and Justification

Prerequisite Criteria

How is the NRSP consistent with the mission?
PLEASE SEE ATTACHMENTS TO THIS NIMMS REPORT TO VIEW THE EXECUTIVE SUMMARY, THE FORMATTED WORD VERSION OF THIS REPORT AND THE APPENDICES (WHICH INCLUDES THE BUDGET)

a. NRSP6 is the only practical source of potato germplasm for US researchers and breeders:

NRSP6 is designated the sole official NPGS project filling the role of working potato genebank for the US. A good way to understand the importance of NRSP6 is to imagine the situation if no genebank was present for an individual researcher wanting to use exotic potato relatives. He would first need to study taxonomic boundaries to understand his material and how it related to cultivars. He would need to determine breeding system, requirements for growth, and interspecific crossing. If it did not exist in the US or he could not find or obtain it from a fellow US researcher, he would need to organize an expedition to Latin America. Since potato is a "prohibited" plant for import, he would have to negotiate APHIS quarantine and wait one or two years. When finally in hand, would he propagate the germplasm disease-free, and advertise it for sharing with all potato researchers worldwide? NRSP6 does and coordinates all these things for the potato research community, avoiding the confusion, inefficiency and costs associated with duplication of these efforts by many individuals. This is not a static process, but must evolve with the advance of science and as needs and opportunities change over time.

b. NRSP6 provides enabling technologies and materials. Germplasm stocks. As described above, providing the germplasm itself enables advances in potato research and breeding. In the past project term NRSP6 has met this need by freely and promptly distributing materials and doing the associated work that supports these distributions.

Germplasm data. NRSP6 provides users with a central source of current germplasm information: What is available in US and globally, taxonomic relationships, natural origin, characterization and evaluation data with respect to useful traits. To do this, NRSP6 must also develop and maintain acquisition; classification; seed increase, inventory, disease status and distribution data. All of this data pertinent to the needs of germplasm users is available 24/7 online.

R&D for best techniques and tools for germplasm collecting, preservation, and evaluation. The genebank is the focus of NRSP6, but we must keep in mind that the genebank has only a sample of what is available in the wild. Thus, study and appropriate action to make the genebank collection the best it can be is crucial. Diversity is the goal, but while the scope of potential diversity we could collect and keep is virtually unlimited, genebank funding is not. R&D that characterizes diversity richness and enables the most efficient techniques for collecting and preservation is of great importance for our own genebank and others worldwide. NRSP6 has become the world leader in developing such information and tools by examining specific practical questions with DNA markers, often using materials from collecting expeditions organized and conducted by genebank staff.

Custom materials for germplasm evaluation. It would not be appropriate for genebank staff to specialize in any one evaluation discipline. Instead, genebank staff expertise in germplasm genetics and handling is used to devise studies, then select and prepare materials for testing in partnership with various extramural scientists with the specific expertise and infrastructure for generating the data.

How does this NRSP pertain as a national issue?
Widespread relevance, need and use of potato germplasm. Potato is the most widely grown and consumed vegetable in the US and world, being among the most palatable and versatile of foods. US and world production has grown impressively in the past five years. Worldwide production grew 13% from 323 to 365 million tons. Potato accounts for about 30% of all vegetable consumption in the US. US consumption has remained fairly steady for the past 40 years, but with percent fresh going from about 50% to about 70% (mostly due to more frozen products), with great economic added value in processing. In the past 5-year project term, production value in the US increased 27% from 3.3 to 4.4 billion dollars, increasing dramatically in many states (see Figure 1).

Exotic germplasm has had great genetic impact and opportunities. More exotic germplasm is available and used for potato than for any other major crop. Over 70% of potato varieties grown in the US have germplasm in their pedigrees from the genebank, and all varieties released in the past five years do. Some estimates have been made of the economic return from germplasm utilization. About 50% of the four-fold advance in potato yields have been due to genetic improvement and about 1% of annual value of all crops may be credited to exotic germplasm. Pro-rated, this is a total of $10-25 million per year for potatoes in the USA.

NRSP6 stocks and research have national value because they...

... appear in most of the improved new cultivars in the 10-15 year pipeline of conventional breeding.

... provide valuable genes in exotic potato that can be efficiently moved to modify popular existing cultivars already having consumer acceptance (e.g., transgenics and Simplot's Innate lines).

... will continue to provide novel technologies that enter the marketplace, like inbred diploid varieties developed by Solynta.

... have a positive impact on all citizens, not just members of the potato industry, since every state has a significant and direct involvement in marketing, transportation and consumption of potato as a major part of the diet of its population. Scientists in every state benefit from advance of knowledge published by researchers using NRSP6 germplasm.

... provide a platform for study and use of quality traits that enhance potato value at the consumer level, which has impact in all states.

... provide a platform for study of health traits like anti-cancer, anti-obesity, and anti-stroke which have great potential impact on economic status and citizen well-being and productivity. Two thirds of Americans are overweight or obese. Inadequate potassium intake would prevent an estimated 100,000 annual deaths due to sodium-induced high blood pressure, not to mention mitigate non-lethal strokes that are the leading cause of chronic, severe disability. Cancer has surpassed heart disease as the leading cause of deaths of all individuals except the very old. Aging baby-boomers are expected to exacerbate these already severe challenges to national health and insurance costs. These medical issues cost US society hundreds of billions of dollars annually.

Rationale

Priority Established by ESCOP/ESS
Challenge 1: We must enhance the sustainability, competitiveness, and profitability of U.S. food and agricultural systems. This can be achieved through lower input costs keeping all other factors steady. Or, quality can improve to support higher prices at the same market share. The optimal scheme for the potato crop is to use germplasm to make gains in all three areas: less input costs, higher yield per area of land, and higher quality. Other initiatives that will contribute to these general goals are increasing net yield by reducing storage losses, and capitalizing on virtual demand by removing the physiological limits to potato production due to the climate, diseases and pests.

Challenge 2: We must adapt to and mitigate the impacts of climate change on food, feed, fiber, and fuel systems in the United States. Potato is cultivated across a broader range of latitudes than any other major crop. Thus, the effects of climate change could be different in different growing regions, and require the screening for multiple new traits in exotic germplasm which can be incorporated into the crop. Genebank staff are actively working on modeling climate change and predicting impact on in situ populations.

Challenge 3: We must support energy security and the development of the bioeconomy from renewable natural resources in the United States. NRSP6 does not address this challenge.

Challenge 4: We must play a global leadership role to ensure a safe, secure, and abundant food supply for the United States and the world. This is the heart of what NRSP6 aims to promote.

Genetic diversity of the exotics at NRSP6 represents the potential diversity of improvements in productivity, quality and resource use efficiency realized in new cultivars.

Challenge 5: We must improve human health, nutrition, and wellness of the U.S. population. As already mentioned, improved potato has outstanding potential to have a significant health and nutrition impact on a population basis because it already has a regular, high level of consumption across all demographic categories in the US. Compare, for example, to blueberries which have famous levels of antioxidants per serving, but are very expensive, and are eaten only in small quantities and irregularly. Potato has had obvious appeal—it is relatively cheap, good-tasting in many forms, and filling. Because of extensive potato cultivation of potato worldwide, reducing the need for chemical inputs in the potato crop through genetic means could significantly reduce the exposure to agrichemicals (manufacture, transport, storage, grower, consumer). Genetic improvements via NRSP6 germplasm are resulting in a more productive, versatile, profitable, nutritious and environmentally safe potato crop.

Challenge 6: We must heighten environmental stewardship through the development of sustainable management practices. Research supported by NRSP6 will continue to find ways to make a crop that is more efficient at using fertilizer and water inputs and can naturally resist pests and diseases. That means less impact on the environment through less use of pesticides.

Challenge 7: We must strengthen individual, family, and community development and resilience. NRSP6 can have an impact on primitive farmers in developing countries who could improve their standard of living and maintain their culture because germplasm inputs gave them a more marketable and nutritious crop (by increasing frost tolerance for high altitude farmers, for example). Food security in developing countries often has a favorable influence on political stability, which reduces the money US citizens must spend to maintain international relations and foreign aid. A healthy US populace can also have a higher standard of living due to more productivity and less need to spend the profits from that productivity on insurance, medical care and government intervention programs.

Relevance to stakeholders

NRSP6 stakeholders are researchers, breeders, those who use their product (producers), food suppliers, and, ultimately, consumers. Here are the reasons why there is a continued need and relevance of NRSP6 service to stakeholders, and why US scientists (and foreign ones) will depend on NRSP6 germplasm more in the future:

1) No other public or private programs have come forward to provide the unique services of NRSP6. Sixty-five years of public support of this genebank has resulted in the collection of over 5,000 items of germplasm for the world's most important non-cereal crop. At least 45% of these are unique. 2) The need for potato research and breeding is increasing. Development of technology has enhanced the quantity and impact of research and publications involving germplasm. There is a US-based international association of researchers devoted to potato with Breeding and Genetics taking a prominent role (The Potato Association of America). There are numerous breeders, hundreds of thousands of seedlings grown for yearly selection, more sophisticated facets of evaluation, and more varieties being released. There is increasing

challenge to gather, format and distribute information with the greater speed and detail made possible with advances in data management technology.

3) Acquisition of germplasm from foreign genebanks or directly from the wild is becoming even less practical for US researchers. Other genebanks have faced financial problems or reorganization which has reduced their capacity to maintain availability of germplasm and services. Countries with native potato germplasm to share are doing so less freely due to policies reflecting feelings of national ownership and problematic expectations of “benefit sharing” that have delayed access from Latin America since 2000. So, dependence on raw materials we have in-country at NRSP6 is greater than ever.

4) Potato is listed as "prohibited" by APHIS, making quarantine testing of all imports for one-two years necessary, at an estimated cost of over $4,000 per item. To avoid the wasted time and expense of having quarantine repeatedly process the same material for multiple importers, we need the coordination, information and preservation provided by NRSP6.

5) We need to reduce agrichemical inputs that are costly and may threaten the health of humans and the environment. We need solutions to legal limitations to use of pesticides and water so producers can stay in business. For farmers and consumers, genetic solutions through germplasm are increasingly important.

6) Physiological constraints such as a need for cold tolerance (applied especially to the mountain growing regions like the Andes but everywhere subject to the global cycle of wider weather fluctuations), heat and CO2 (global warming), water and fertilizer use efficiency (loss of water rights, phosphates in lakes, nitrates in groundwater, energy costs for pumping water and making fertilizer) have increased, as well as a general need to increase the adapted range of potato to production areas where it would increase food security and benefit the world economy. All these point to an increasing need for the "new blood" available in NRSP6 exotic germplasm.

7) Technology has increased the possibilities for germplasm use making it more valuable. The prospects of easily identifying and mining genes from exotic germplasm (reducing the long and expensive process of conventional breeding) makes the service of NRSP6 even more valuable to stakeholders.

Full documentation of the project accomplishments is provided on the project website link "Administrative Reports" : http://www.ars-grin.gov/nr6/admin.html. A summary text form is provided below, with formatted quantification in the cited Appendix. Note also that the titles of staff publications in Appendix B indicate how NRSP6 staff discovered attributes of the germplasm that make it more useful to germplasm cooperators.

Implementation

Objectives

1. Acquire germplasm to expand genetic diversity contained in the US Solanum germplasm collection. Over 175 new stocks were added by USA collecting, requests from cooperators, and requests from genebank staff (see Appendix A1).
2. Classify accessions with species names which will serve as stable identifiers, and promote efficient utilization. Species names were assigned to all new accessions. Taxonomic studies using both molecular and classical techniques were employed to determine stable species boundaries, condensing the over 200 species names of the past to less than 100. See Appendix A2 for species list and changes.
3. Preserve NRSP6 germplasm in secure, disease-free, and readily available form. The genebank now has nearly 6,000 stocks as seed populations and clones. These were preserved with maximum genetic integrity in viable, disease-free form available for distribution. This effort included maintenance of data, performing seed and in vitro increases, purity tests, disease tests, germination tests, chromosome counts, field grow-outs, better scheduling of pollination to catch parents at their peak (see Appendix A3).
4. Distribute germplasm, associated data and advice to all researchers and breeders in a timely, efficient, and impartial manner. Orders remained strong in the past project term, and were filled within one week of receipt. Details by state and region are presented in Appendix A4.
5. Evaluate the collection for as many important traits as possible. Unpublished screening data of experiments conducted by cooperators was summarized and uploaded to GRIN. Evaluation initiated by staff and done in-house or with cooperators covered a broad range of topics pursuant to more efficient mining of the value of NRSP6 germplasm. See Appendix A5 for scheme for systematic mining and study of germplasm traits.

Projected Outcomes

1. Acquire germplasm. Most of Latin America is currently closed to US germplasm collecting. [We will continue work to better understand the status and vulnerability of the in situ germplasm resource, particularly related to climate change. We will also pursue new opportunities for research-oriented collecting in Peru and Mexico, and expand frost and wart resistance breeding with germplasm donor countries. We will pursue extension of clean tuber seed production systems in Latin American countries that need it to systematically evaluate NRSP6 germplasm.]. Annual collection trips in the US will be made to acquire new germplasm and to gather materials for research investigations on collecting methods and the relationship of in situ to ex situ genetic diversity. [We will study predicted impact of climate change models. We will test new collecting technologies for pollen, meristems in antibiotic medium, and anti-insect treatments, and more vigorously pursue opportunities for cooperation with local botanists.] We will continue to survey researchers for their needs, and assess gaps in the collection, then initiate the corresponding imports.
2. Classify germplasm. The ARS taxonomist will continue to assign species names to all items in the genebank and do the research and evaluation work necessary to make the classification system stable and useful. NRSP6 staff will continue to evaluate and develop mutants and other selections that will be formally deposited in the genebank.
3. Preserve germplasm. Propagate. Increase seedlots at the rate of greater than 200 per year for a 25-30 year cycle. Conduct in vitro transfers needed to maintain clonal collection

viability. Safeguard. Maintain on-site and remote backup collections at the National Center for Genetic Resources Preservation (NCGRP) at Ft. Collins, CO. Maintain health. Continue vigorous, comprehensive testing to minimize the possibility of distribution of diseased stocks. [We will set up better local quarantined greenhouse and sanitation methods to contain any suspected infections. We will investigate and develop a program for virus-freeing any infected genebank or research stocks.].

4. Deliver germplasm and services. Continue the rapid delivery of high quality germplasm and information. Continue to advise on selection of research germplasm, and the most appropriate form and techniques by which to study or hybridize it. To do so, continue to invest time in keeping "in touch" with the science by studying the literature, training students, participating in professional societies and collaborating with many state and federal potato researchers in the US and with our counterparts in potato genebanks abroad. [We will expand the website offering of germplasm handling tips to include short video clips].
5. Evaluate germplasm. Continue conducting preliminary screening and characterization for novel traits and novel applications of exotic germplasm. [We will do additional cooperative evaluation and development work on traits discovered/developed in the past project term: tuber pH, antioxidants, tomatine, anti-appetite and anti-cancer chemicals, folate, tuber calcium, frost tolerance, Zebra Chip resistance, tuber greening after illumination and associated glycoalkaloids, gibberellin and floral mutants. We will use our tissue culture facilities and expertise to start working on interaction of microbes and potato, particularly variation for potato as a prebiotic. We will genetically characterize the new floral mutant Coronita. We will test all raw and advanced germplasm for value in breeding orange-fleshed Colombian Criolla-style specialty potato, test these for nutrients and anti-nutrients, and pursue inbred Criolla lines. We are preparing tuber flesh samples from large subsets of the collection (like all the named cultivars) in preparation for contracted systematic evaluation panels of tuber quality and nutritional components. We will continue remote greenhouse and field growouts in Florida, Arizona, California, and Wisconsin that expand our capacity to produce tubers for destructive tests, or provide a shortcut to selecting best tuberizing seedlings of exotic hybrids from segregating families.]

Management, Budget, and Business Plan

Genetic diversity management. DNA-marker-based studies will show us where genetic diversity is concentrated and vulnerable to loss, so we can prioritize stocks for preservation and optimize techniques as needed. [We will continue to test methods of selecting core collections for more efficient germplasm sampling. We will continue DNA-marker-based studies aimed at understanding relative genetic heterogeneity of germplasm subgroups and how this impacts sampling when collecting, preserving and evaluating the germplasm. We will continue studies on efficiency of rapid visual categorization (cogs) for partitioning diversity within taxa.]. Technical research. Studies will be done to improve the efficiency of growing, mating, and storing the stocks, providing results that help the genebank and our clients. [We will investigate more porous potting medium for over-watering protection, techniques for promoting flowering, systems for training plant canopy for better growth, fine tune fertilization and germination methods. We will test fertilization effect on long-term germination. We will use our tissue

culture facilities and expertise to start working on use of microbes for bioassays and as selection agents. We will systematically test bridge-crossing techniques to bring S. jamesii and similar primitive diploids into the breeding pool. We will continue breeding toward an ideal universal diploid cultivated tuberosum parent for introgressing diploid exotic wild germplasm.]

Records. Maintain local data records and those on-line in GRIN and Intergenebank databases [We will transition to the new GRIN. We will make photographs and tissue samples of the field tubers of the cultivar collection and post them online. We will digitize PTIS herbarium records and link them to GRIN provenance records. We will keep the PCGC Vulnerability Statement document updated and revise the NRSP6 Procedures Manual.].

Human resources. Project direction will be accomplished through a Technical Advisory Committee and USDA/ARS National Plant Germplasm System leadership. Local administration is by the ARS Project Leader, ARS and UW staff and associated ARS scientists and administration at Madison. We will: Manage staff time and budget to maximize efficiency and flexibility. Strive to make prudent decisions on what we should do in-house and what should be contracted or purchased. Direct experienced base staff to tasks requiring technical expertise and reserve routine work for part-time staff. Hold regular group meetings to make sure the team is working together cooperatively and safely. Conduct annual self-review of overall project progress each year with local staff, and individual staff performance evaluations. Hold TAC meeting on-site every other year to report, tour facilities, provide "face time" with all local staff, and solicit management input from national experts. Each year prepare the Annual Report, UW Hort Department Professional Activity Report, and ARS Performance Plan Appraisal, as ways to invite feedback on methods, focus and management.

ARS contributions. Associated base research budgets from ARS scientists and various sources of outside grant funds also support technical research, labor, supplies and equipment that directly enhance NRSP6 service. See Appendix E and F for details of structure and contributions. ARS administration costs at the Midwest Area and National Levels are also significant. USDA/ARS and USDA/APHIS also provide data management services through GRIN, and for quarantine, respectively. University of Wisconsin contributions. The University of Wisconsin Department of Horticulture (HORT) will provide lab and office space for on-campus R&D that supports the NRSP6 service, with administrative and secretarial support for Madison personnel provided jointly by ARS and HORT. The University of Wisconsin Peninsula Agricultural Research Station at Sturgeon Bay (PARS) will continue to be the headquarters of NRSP6. PARS will contribute much of the needed facilities and associated resources: 10 greenhouses, 5 large screen houses, office and storage buildings, two labs, field plots, travel and farm vehicles, security and maintenance, utilities (including the major input of heat and light for greenhouses), plus some secretarial service. We will also use greenhouse and field resources at remote locations with cooperators at the UW-Hancock field station. HORT also provides administration of personnel for local state employees and graduate students associated with the genebank. UW provides accounting services for the NRSP6 budget.

Grants and Collaborators. ARS scientists will continue to seek grants and engage numerous state, federal, international, and industry collaborators who contribute expertise, facilities, equipment and funds to joint projects of mutual interest. Project Leader will continue as chairman of the

Crop Germplasm Committee, which provides ~$10K in germplasm evaluation funds each year, expressly intended for evaluation of NRSP6 genebank stocks.

No fees for service. Charging fees for services has been suggested several times in the past, but always determined to be impractical and counterproductive because implementation would be costly and complicated, it would depress germplasm distribution and use, and, it would contradict USDA policy of free exchange and perhaps inhibit donations of germplasm to NRSP6.

MRF contributions. NRSP6 is the NPGS working genebank for the top vegetable, so is perpetual in nature and national in scope. Over 25% of germplasm distributions go to ESCOP scientists. For over 65 years, the important elements of funding and administration for NRSP6 have developed as a partnership of SAES, USDA/ARS, and UW. Continued significant funding and technical/administrative inputs on a multistate basis are seen as necessary to keep this partnership healthy and maintain this project's impact and efficiency.

Industry contributions: Gifts from private companies prove the practical value of NRSP6, and keep us tuned to the needs of the industry. Such gifts totaled over $45K in each of the past two years. Robust support of this kind will continue to be sought. BUSINESS PLAN: The FY16-20 budget proposal is to continue at a base $150K per year. See budget tables and background in Appendix F for details.

Integration

There is a close working relationship among the genebank participants (ARS, PARS, UW). In brief: The Project leadership is composed of ARS employees who must interact with ARS administration and be subject to performance evaluation related to NRSP6 service appointments. ARS administration is part of the NRSP6 TAC. PARS provides the physical location of NRSP6, and coordination between the objectives of the two programs takes place on a daily basis. Local NRSP6 staff are both UW and ARS employees. Part time staff are UW. ARS staff share equipment and participate in cooperative research with their state HORT peers. Thus, the UW HORT potato research program is fully engaged in NRSP6 project activities pursuant to the enhancement of NRSP6 service. NRSP6 has led the effort to coordinate the activities of world genebanks through the Association of Potato Intergenebank Collaborators (APIC). NRSP6 is a fully-engaged member of the National Plant Germplasm System. Staff attend all meetings of the advisory committee for genebank directors (PGOC) and the committee for the national germplasm management database (GRIN). NRSP6 staff are fully engaged in state potato programs. We participate in scientific, grower meetings, and field days and conduct collaborative research with a view to better understanding the needs of the industry and getting input regarding how NRSP6 can meet them. NRSP6 maintains email contact with 437 active cooperator/germplasm users, a 17% increase over the past project term.

Outreach, Communications and Assessment

Audience and visibility. The primary recipients of our service are breeders and the scientists doing research that supports breeding. We also serve researchers seeking to optimize germplasm management, and home gardeners and non-professional botanists. We have a general educational

outreach through brochures, website, and popular press. NRSP6 staff routinely give tours, talks to public school classes and other groups. We give advice on germplasm use technology, or in personal correspondence associated with germplasm orders or cooperative research and evaluation projects.

NRSP6 staff:

Attract publicity in popular media and communicate to scientists through published scientific research papers involving NRSP6 germplasm.

Make collaborative partnerships with high-profile national and international potato experts and contribute to scientific meetings.

Serve in leadership roles in potato research associations and journals (Potato Association of America, American Journal of Potato Research, Crop Germplasm Committee).

Establish an email group and website with which to keep in regular contact with germplasm users and participate fully with GRIN.

Extend global outreach and awareness of NRSP6 through involvement in the Association of Potato Intergenebank Collaborators (APIC) and international cooperators on an ad hoc basis.

Train Summer Undergrad Student Interns on mini-research projects and general operations of a genebank. Some such work leads to formal publications.

Engage stakeholders. NRSP6 established an email group and offers stocks and services 3-4 times per year. We will continue to ask Potato Assn of America Breeding and Genetics section members for suggestions on how to improve service each year. Regional Tech reps annually poll germplasm recipients about satisfaction with service. As CGC chair, Project Leader must survey germplasm evaluation needs. We correspond meaningfully with recipients of each order to make sure their needs were completely met, ask for suggestions or other ways we could improve service.

Method to measure accomplishments and impacts. The most important documented evidence with which to measure impact is the advance of practical knowledge about germplasm reflected by formal research publications using NRSP6 stocks and the presence of exotic germplasm in pedigrees of new cultivar releases (that practical knowledge transformed into a better crop). NRSP6 publications and use of stock in new cultivars is documented in Appendix B.

Communication pieces. Locally generated brochures, web pages, posters at meetings.

Mechanisms for reporting. Annual Report, notes of accomplishments and plans in preliminary pages of annual Budget Requests, and TAC meeting minutes are on the web. NRSP6 has always had the philosophy that the best and only way to catch the attention of germplasm users, communicate effectively with them, and understand their needs is to become their peers by being

germplasm users ourselves and vigorously participating in all aspects of the science, including formal research that culminates in publication in peer-reviewed journals.

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