Germplasm Conservation and Research

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Plant Germplasm Conservation and Research

A three-way partnership
ARS ~ CSREES ~ SAES

The National Plant Germplasm System (NPGS)

The National Plant Germplasm System

- Responsibility for conservation, maintenance, preservation, and use of the Nation's plant germplasm resources.
- A federal-state collaborative program
  - Over 50 years of service to U.S. agriculture
  - Funded through a partnership of State & Federal resources.
- Agricultural Marketing Act of 1946
  - Legal basis for the federal / state partnership that emerged for managing and preserving germplasm resources.

The National Plant Germplasm System:

More valuable today than ever before

More valuable than ever before:
Converging political & scientific factors

- More flexibility in American crops & cropping systems:
  - A long era of security and stability appears to be ending
  - Climate change, globalization, natural disasters, terrorism
- International markets increasingly quality-exigent
- Consumer interest in diversity in foods, food production
  - Fruits, vegetables, and grains
  - New market niches, additional value and jobs
- Access for collecting new germplasm is increasingly restricted
- New tools: Molecular tools and informatics
  - More efficient collection management; more powerful characterization

Realizing this value requires:

- Ability to use genetic diversity
  - Quickly
  - With knowledge
  - With creativity

CSREES funding for the NPGS

- **Over $3 million/yr through CSREES** (5-yr average), from 3 sources:
  - "Off-the-top" 1% of total Hatch appropriation
  - **Multistate Research Fund** (MRF) (next 25% of Hatch approp.)
  - Smaller amount from Hatch allocations to each state
- **Five NPGS projects: 4 multistate research projects, 1 nat'l. research support project (NRSP)** -Each corresponds to an **active** collection **site**
- State-allocated Hatch funding to SAES researchers in these projects
- **Support through CSREES varies by region**. Five-yr averages:
  - S-9 $1,066,576/yr W-6 $624,171/yr
  - NC-7 $ 841,026/yr NE-9 $309,110/yr
- About 10 % of ∑$ for the four projects
- **ARS contributes 90% of funding for the five NPGS projects, most of it directly to the active sites**

Decision-making re NPGS funds awarded through CSREES

Hatch funds to NRSP:

- Allocation to specific NRSPs decided at ESCOP level

MRF Hatch funds to the four multi-state NPGS projects:

- Decided by regional SAES directors associations

State Hatch funds to SAES researchers collaborating with NPGS:

- Decided by each state's SAES director

State funding sources:

- Host states of NPGS active sites contribute varying $, S-9 >NC-7 > W-6 > NE-9

NPGS Management

- Primary responsibility for management of the NPGS rests with ARS
  - ARS organizes the network of federal-state committees that coordinate NPGS priorities and activities by crop, by region, and nationally
- SAES collaboration in NPGS management occurs through the four multi-state NPGS projects and the NRSP. Each project has:
    - An Administrative Advisor from regional SAES Director's Office
    - The single NRSP has four AAs, one from each region
    - A CSREES liaison
    - SAES scientists are largest member group in multi-state NPGS projects
    - ARS scientists also participate, esp. leaders and scientists at regional active sites
- Consequently, CSREES funding supports multiple levels of SAES participation in planning and managing the NPGS

NPGS Management: Committee interactions

A comprehensive state-federal system for input to the planning and management of the NPGS.

- The four multistate committees and the NRSP
- Over 40 Crop Germplasm Committees, experts from the federal, state, and private sectors, convened by ARS
- Plant Germplasm Operations Committee: leadership of all of collection sites; an ARS committee
- New: National Plant Germplasm Coordinating Committee: support to communication among the decision makers in the ARS, CSREES, SAES partnership

The National Plant Germplasm System

Economic Research Service:

- Contributes via economic appraisal of germplasm activities
- Benefits of $ billions for the U.S. and the world
  - E.g.Day-Rubenstein *et al*., 2005

Objectives of the NPGS

- To achieve these benefits, the NPGS projects work on four objectives:
  1. Conserve;
  2. Characterize and evaluate;
  3. Understand;
  4. Use *('utilization')*

- Use includes:
  - Source of characteristics for germplasm enhancement/ breeding
  - Sometimes, directly as varieties
  - Materials for basic research (e.g., biology, pharmacology)

- Examples of NPGS activities
  - From FY 2003 and 2004

NC-7 Conservation, Management, Enhancement and Utilization of Plant Genetic Resources (Ames IA)

- *Emphasis: 12 crops / crop groups*
  - Maize, sunflower, root and bulb vegetables, forage and turf grass, crucifer, herbaceous ornamentals, woody landscape plants, leafy vegetable, cucurbits, clover and special purpose forage legumes
- Approximately 84,100 accessions

Activities in NC-7: Two examples

1. Agronomic crops

Characterize and evaluate -- Utilize:

- KANSAS STATE UNIVERSITY
  - Accessions of Brassica napus from the NC 7 plant introduction station (PI station; active site collection)
  - Used in developing germplasm base for breeding adapted canola cultivars for the southern Great Plains
  - Canola in a Great Plains rotation can net additional $50/acre compared to wheat alone

Activities in NC-7

2. Horticultural Crops

Evaluate -- Understand -- Utilize:

- OHIO STATE UNIVERSITY
  - In Great Lakes, forecasting models predict bacterial infection poorly; growers default to calendar application of fungicides
  - Lack of resistance to bacterial diseases adds to cost of production: fungicide costs in addition to yield and quality losses
  - Interspecific populations using *Lycopersicon esculentum* + wild tomato species *L. pimpinellifolium* and *L. hirsutum* for:

    plant breeding, trait introgression, and gene discovery.
  - Discovered two *L. esculentum* QTL associated w/improved color; two *L. hirsutum* QTL for resistance to bacterial canker
  - Will lead to varieties with higher level of resistance to bacterial disease.

NE-9 Conservation and Utilization of Plant Genetic Resources (Geneva NY)

- *Emphasis: 12 crops, or crop groups*
  - Tomato, onion, selected crucifers, celery, winter squash, radish, other vegetables, and buckwheat
  - Clonal collections include apple, grape, and cherry
- Approximately 11,800 accessions

Activities in NE-9: One example

Horticultural Crops

Utilize:

- CONNECTICUT AG. EXPT. STATION, NEW HAVEN
  - Compare vegetable accessions from NE-9 Regional Plant Germplasm Unit w/standard varieties,
  - Resistance to key insect pests of cucurbits, beans, eggplants, brassicas
  - Increased regional capacity for vegetable breeding and seed production
  - Selection for traits needed in regional vegetable production.
  - Cooperation with organic growers

S-9 Plant Genetic Resources Conservation and Utilization (Griffin, GA)

- *Emphasis: 15 crops/crop groups*
  - Capsicum, clover, special purpose forage legumes, cucurbit, warm season turf grass, peanut, sorghum, sweet potato, cowpea, vegetables (okra, pepper, watermelon, squash, eggplant, gourds), mung bean, legumes (guar, winged bean), bamboo, castor bean, sesame, pearl millet
- Approximately 47,800 accessions

CSREES
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Activities in S-9: One example

Agronomic crops -- Utilize:

- CLEMSON UNIVERSITY
  - Experimental soybean germplasm line dev'd by Soybean Germplasm Collection, ARS, from Chinese parent lines
  - Crossed with elite SC glyphosate-tolerant lines to combine:
    - New diversity of genes for seed yield
    - With genes in the adapted lines for nematode resistance and agronomic characteristics for SE U.S.A.
  - Another germplasm line, resistant to root-knot nematode
    - Crossed with adapted S.C. cv. Dillon, to combine
      - Improved nematode resistance
      - High seed yield
      - Acceptable agronomic traits.
  - Adding diversity to narrow genetic base of adapted soybeans for the SE

W-6 Plant Genetic Research Conservation and Utilization (Pullman WA)

- *Emphasis: 9 crops/crop groups*
  - Forage and turf grasses, beans, cool season food legumes (pea, lentil, chickpea, fava bean, lupine, etc.), lettuce, safflower, onion relatives, and forage legume crops, selected ornamental and medicinal species
- Approximately 72,400 accessions

Activities in W-6: two examples

1. Agronomic Crops

Understand -- Utilize:

- NEW MEXICO STATE UNIVERSITY
  - Hybrids between populations from NPGS alfalfa core collection
    - Significant heterosis for forage yield; several hybrids outperformed best commercial varieties.
    - Yield positively associated with genetic diversity among parents.
    - One parent appears to possess high water-use efficiency
    - Strategies that use data on molecular genetic diversity + agronomic performance of parents = greatest chance of identifying parents w/maximum heterosis

Activities in W-6

2. Horticultural crops

Characterize and evaluate--Understand:

- OREGON STATE UNIVERSITY
  - Hazelnut germplasm
    - Actively accessing new germplasm, sharing with NPGS
    - Breeding program evaluates for morphological traits, DNA markers, and susceptibility to eastern filbert blight (EFB)
  - Complete-to-good EFB resistance in accessions from Serbia, Ukraine, Turkey
  - Complete EFB resistance transmitted to offspring of one Georgian and one Russian accession

Research in the previous examples :

- conducted by SAES researchers,
- within the NPGS funding & management structure,
- using Hatch funds through CSREES.

CSREES also funds research in genetic resources and biodiversity:

- conducted by any *bona fide* researcher
- complementary to the NPGS,
- though not part of the NPGS structure.

CSREES funds additional, complementary research in genetic resources and biodiversity

- Knowledge Area (KA) 202:
  "*Plant Genetic Resources and Biodiversity*":
  - Acquire, preserve, characterize, evaluate, and use plant germplasm; germplasm enhancement and pre-breeding; botanical studies
- Germplasm from many sources
  - NPGS, international research centers, SAES breeder nurseries, researcher contacts with collaborators in other countries or private sector, SAES collections

CSREES funding for all KA 202 projects

- Total about $10.5 million/yr (including NPGS)
  - Hatch funds (add'l. $3 million) ± $6 million/yr
  - Special Grants ± $2 million/yr
  - "Other" (e.g., IFAFS; Federal Admin) ± $900,000/yr
  - Nat'l. Research Initiative (NRI) ± $825,000/yr

(5-yr averages)

State Hatch-funded KA 202 germplasm research: Two examples

1. Agronomic crops

Characterize and evaluate -- Utilize:

- *TEXAS A&M UNIV*., BREEDING & GENETICS OF CORN
  - Transition area between tropical and temperate zones
    - *Allows introgression of tropical germplasm w/temperate material*
  - Temperate inbreds -- high yield, stalk quality, early vigor
  - Tropical and subtropical germplasm -- new alleles for resistance / tolerance to biotic and abiotic stresses (e.g., reduced aflatoxin, drought & heat tolerance), kernel quality
  - Searching for new alleles for nutritional value for food/feed
  - Work will contribute to diversity of corn germplasm in the U.S. for food safety, sustainable productivity, and value-added profitability

State Hatch-funded KA 202 germplasm research

2. Horticultural crops

Characterize and evaluate -- Utilize:

- RUTGERS UNIV., BREEDING AND GERMPLASM ENHANCEMENT FOR NEW JERSEY CRANBERRY AND BLUEBERRY INDUSTRIES
  - Blueberry breeding for improved productivity, fruit quality, disease and insect resistance, and human health attributes.
  - Aphid resistance in wild blueberry *Vaccinium darrowi*
  - *V. darrowi* also offers potential immunity to second stage of mummy berry disease
  - 63 interspecific hybrid plants selected based on flavor, yield, plant health, and maturity

NRI and the NPGS

- Recently, NRI subprogram 52.2 "*Genetic Processes and Mechanisms of Agricultural Plants*" began inviting applicants to use NPGS materials in research
- Other NRI sub-programs may use NPGS materials, e.g.,
    - 52.1 Plant Genome
    - 22.1 Agricultural Plants and Environmental Adaptation
    - 53.0 Developmental Processes of Agricultural Plants
- Also, because ARS is eligible to receive NRI funds --
    - Creates an additional form of interagency collaboration, i.e., CSREES-funded ARS plant germplasm research

NRI- funded research using NPGS materials: Three examples

1. *Agronomic crops: Characterize and evaluate – Understand*

- UNIV. OF GEORGIA
- MOLECULAR APPROACHES TO INSECT RESISTANCE IN SOYBEAN and PYRAMIDING BT AND SOYBEAN GENES FOR INSECT RESISTANCE
  - Multidisciplinary: entomology, molecular genetics, breeding
    - How genes for insect R interact; new insect R management strategies
  - Crossed cultivated line with NPGS germplasm lines
    - All combinations of an engineered insect R gene (Bt), with insect-resistant soybeans-- evaluated in field, greenhouse, growth chamber
    - Most combinations w/Bt=neutral or detrimental; one combination resistant to many insects, incl. insects selected in lab for R to Bt
    - Use of this combination may lead to plants with stable resistance to many insects and strategies to delay development of resistance in insects

NRI- funded research using NPGS materials

2. Horticultural crops

Characterize and evaluate -- Understand

- ARS, USDA
- GENETIC DIVERSITY OF WILD APPLE ACCESSIONS IN THE NPGS
- New wild apple germplasm from China, Turkey
  - Determine genetic relationships among wild Rosaceae accessions in the NPGS (existing and new)
  - Identify a group of individuals that represents the overall genetic diversity of wild Malus collections with the smallest number of individuals (core collection)

NRI- funded research using NPGS materials

3. NRSP-6: Inter-Regional Potato Introduction Project (Sturgeon Bay WI). Approx. 5,600 accessions.

- *Characterize and evaluate* -- *Understand*
  - UNIV OF WISCONSIN. A CLADE-BASED SEARCH FOR GENOME REARRANGEMENTS AND USEFUL DIVERSITY IN SOLANUM
    - Late blight, one of most important diseases of potato, worldwide.
    - Wild potato relative *Solanum paucissectum*, a potential new source of late blight resistance
      - Differential reaction of *S. paucissectum* with isolates of *P. infestans* suggest new major resistance genes, different from the R genes previously described from *S. demissum*
      - 1st genetic map and 1st resistance genes from a member of this clade (group *Solanum* series *Piurana*) = new diversity for cultivated potatoes

IFAFS-funded integrated project

Initiative for Future Agricultural & Food Systems Last example

Horticultural crops -- *Characterize and evaluate -- Utilize:*

- **CORNELL** (Plant Breeding + Hort. Depts; Coop. Extension);
  NE ORGANIC FARMING ASSOC. of NY, Inc.; ARS, USDA
- THE PUBLIC SEED INITIATIVE (PSI) FY 2002-04
- Changes in seed industry → varieties selected for average national growing conditions; fewer varieties for NE.
- Worked w/ farmers + small-scale seed co's., training in vegetable breeding and seed production; on-farm breeding
- Helped growers access & evaluate plant materials from NPGS + public breeders, identify varieties for small seed companies and organic systems
- Short-term results: Over 40 community seed days or seed demonstrations; 46 varieties available to farmers and gardeners; 43 commercial licenses (at least 5 via organic seed catalogues); about 1000 active participants + over 7000 observers at field days and fairs
- Long-term potential to increase number and quality of varieties offered by remaining and new seed companies; improve productivity/ viability of NE agric.

CSREES EDUCATION RESEARCH USDA EXTENSION

Measurable outputs from CSREES-funded NPGS multistate projects, FY 2003-2004

Value added steps:

Accessions obtained	*122, + 1 'collection'*
Accessions characterized or evaluated	*2990, + 23 'collections'*
New sources of valuable traits identified	*At least 6*
Data entered in GRIN (nat'l. e-database)	*5109, + 4 'collections'*
New /improved conserv./preserv. methods developed /implemented	*5*
New introgression pop'ns. from crosses to breeder materials	*At least 9*
Advanced inter-specific populations dev'd	*11*
New genetic markers ID'd/new genes cloned	*129*
Germplasm released or licensed	*10*
Varieties released	*At least 21*

Measurable outputs from additional CSREES projects on "Genetic Resources and Biodiversity" (KA 202), FY 2003-2004.

Value added steps:

Accessions characterized or evaluated	33, 586
New sources of valuable traits identified	42
New populations developed from crosses	63
Advanced populations developed	114
New methods developed	15
New genetic markers identified, new genes cloned	172
Germplasm released or licensed	89
Varieties released	94
Patents or Plant Variety Protection Certificates	62
Species included in reported research	71
Major journal publications	553
Extension bulletins, popular publications	65

Plant germplasm is a resource for the future . . .

. . . **if** it is **collected and conserved;**

. . . **if we understand** it and know how to **use** it.

Inter-agency partnerships are strengthening our national ability to manage, understand, and use germplasm.

The National Plant Germplasm System: Where are we?

- Fifty years of work on:
  - Management, operations, collaboration
  - Strategic input and planning
  - Funding mechanisms
- Much less work on:
  - Communicating --
  - To a broad range of audiences--about:
  - The excitement of the NPGS, and
  - Why and how the NPGS is valuable to them

What would the public want to know about NPGS?

A. Example from the scientific public:

Questions to NPGS from the Subcommittee Chair for Germplasm, National Research, Extension, Education, and Economics Advisory Board (NAREEEAB).

- NAREEEAB is a statutory board that reports to the Secretary of Agriculture and to Congress.
- The Subcommittee Chair for Germplasm was Dr. Marty Apple, from the Council of Scientific Society Presidents

What would the public want to know about NPGS? Example from the scientific public:

Information requested, not available, or not in handy form:

- What traits are most desired in each species? What traits are characterized? What remains to be done?
- What are key accomplishments of the USDA Germplasm System? Pre-1900; 1900 to 1950; 1950-85; 1985-2000; 2000-present
- Who are NPGS's customers? What do they value?
- What ethical rules are required of customers? What are the relationships with the source nations?

In the current system, what are the:

- Standards of excellence,
- Productivity measures, and creativity measures.

How does the NPGS learn and improve?

What would the public want to know about NPGS? Example from the scientific public:

Information available but changes urged:

- Why is this whole system needed? What is the bold, compelling mission and vision? What are the specific goals of USDA Germplasm System, and how is annual progress measured on each?
- Are there under-appreciated threats to the NPGS?
- Are there opportunities for the future not yet addressed?
- Are there needs unmet in the current status? What is being done?

What would the non-scientific public want to know about the NPGS?

- The non-scientific public will probably have an increasing role in the decision making process.
- So anticipating and answering their questions is important.
- Do we have a sounding-board for the non-scientific public?