

USDA Agricultural Research Service
Assessment of National Program 301: Plant, Microbial and Insect Genetic
Resources, Genomics and Genetic Improvement
September 2005

Executive Summary

A panel of ten geneticists, plant breeders and molecular biologists was convened in Beltsville, MD September 14-15, 2005 to conduct a 5-year retrospective review of USDA-ARS NP301 (Plant, Microbial and Insect Genetic Resources, Genomics and Genetic Improvement). NP301 represents the largest single ARS national program with over 180 projects encompassing ten different research problem areas. The panel was provided with a retrospective accomplishment report that focused on the overall impacts of selected projects within the national program. This was meant to be an overarching review rather than a project by project review, which are conducted by the Office of Scientific Quality Review. In addition to this report, panelists were able to draw on other resources, including publications, databases and professional working knowledge of the research areas within NP301. The panelists were provided a brief overview of NP301 prior to our deliberations by USDA-ARS leadership including:

Dr. Judy St. John, Deputy Administrator, Crop Production and Protection
Dr. Kevin Hackett, National Program Leader, Biological Control
Dr. Kay Simmons, National Program Leader, Grain Crops
Dr. Peter Bretting, National Program Leader, Plant Germplasm and Genomes

The panelists also wish to thank program staff including Ms. Marilyn Low, Valorie Butler and Rosetta Proctor for their assistance with the review. We also want to thank Dottie Tapscott for her assistance with travel. Finally, we are most grateful to Dr. Caird Rexroad for his participation in the exit interview with the panel. Support for this critical national program at the highest levels within the agency was quite apparent to the panel.

The accomplishments report of NP301 was developed by the national program leadership staff based on impact statements submitted by ARS scientists. These accomplishments were assessed against commitments (goals and objectives) identified in the action plan created at the beginning of the five year cycle. The panelist reviewed the action plan, in addition to the accomplishment report. Our recommendations are outlined under each of the problem areas and are largely based on the following assessment criteria:

- Crop varieties or improved germplasm released
- Crop germplasm accessions conserved and distributed
- Crop genetic/genomic tools developed
- Crop genome information provided to users
- Technology that has been publicly released, patented or licensed, and/or commercialized
- Influence on other researchers in the same or related fields
- Advancement of scientific knowledge

- Major agricultural problems ameliorated, mitigated or solved
- New or improved scientific methods, tools or technologies developed by ARS and adopted by others (customers, stakeholders, etc).

Ratings in each of the problem areas ranged from low to high. A low rating should not be interpreted as a lack of support for the problem area, but rather the limited impact that the panel observed in the given problem area. This may be a result of limited data presented. Overall, the review panel was impressed by the breadth and depth of accomplishments under this national program area. Based on the number of projects within NP301 and the investment of resources in these projects, it is clear that USDA-ARS sees this national program as an important mission within the agency. The improvement of crop species for agricultural productivity is of critical importance to U.S. and world agriculture. USDA-ARS is in a unique position given its long term commitment to research of national importance to make lasting impacts on the fields of science represented within NP301. In particular, the panel applauds investments in core research programs that seek to conserve germplasm, genetic stocks and research collections, as well as those programs focused on the development of, and implementation of bioinformatics databases. In a number of cases, it is quite clear that USDA-ARS scientists are leading the way in research on problem areas represented within NP301. In most cases, collaborations with other public research scientists are a critical component of ARS programs. The agency is encouraged to continue to support and encourage these collaborations, as it is a proven way to leverage resources and expand the expertise base of ARS.

The panel is very encouraged by the planning process that leads to action plans for each of the national program areas. The involvement of the broad research community, as well as stakeholders from the agricultural community is critical to the long term success of ARS. An overall recommendation of this panel would be to put in place a number of specific advisor councils to keep various research components and problem areas closely tied to the user community. As the national intramural research agency for Agriculture, USDA-ARS must stay connected to customers and this goes beyond the stakeholder workshop that begins the five-year work cycle. Specific recommendations in this regard are highlighted under each problem area when appropriate.

RESEARCH COMPONENT I: GENETIC RESOURCE MANAGEMENT

Overview

The long term success of U.S. Agriculture depends on the collection, evaluation and safeguarding of plant, microbial and insect germplasm. The availability of these resources to the broad research community is crucial to the improvement of germplasm for the benefit of agriculture. This research component represents a mission that is largely unique to USDA-ARS, but requires strong collaboration with other public research organizations in the U.S. and international agencies. Key to the success of USDA-ARS in addressing this research component is the development of unique facilities to house and evaluate these genetic resources. The review panel compliments ARS for their efforts to increase this infrastructure in recent years, as these new facilities represent a valuable national resource. We applaud the efforts to expand the germplasm collections during the period of this review and the efforts to insure their safety through sample duplication.

Recommendation: The panel recommends that USDA-ARS involve the user community in the establishment of clear priorities for managing genetic resources. A Genetic Resource Management Advisory Committee should be convened to assist the agency in identification of critical gaps in collections based on current and future needs of the user community. This committee could include curators of USDA-ARS collections, ARS scientists, plant breeders, international agencies and other key stakeholders.

Problem Area I.a: Safeguarding Threatened Genetic Resources and Associated Information.

Panel Rating: medium impact

This is a critically important research area where USDA-ARS clearly serves a national need. No other public research organization is in a position to safeguard threatened genetic resources for U.S. agriculture. The identification of gaps in the germplasm collections, and subsequent filling of these gaps is a very high priority within NP301. In many cases, it appeared to the panel that collections were driven more by the threat of loss of genetic material from particular geographic regions rather than a clear prioritization of gaps in the collection. The panel felt that efficiencies in collections were largely lost due to the lack of a clear strategic plan for filling gaps. In addition to germplasm collections, USDA-ARS has a unique opportunity, and perhaps a unique responsibility to safeguard many of the threatened special collections coming out of modern molecular studies of plants, microbes and insects. These resources include mutant lines used for gene “tilling” projects, genetic stocks and cytogenetic stocks.

Recommendations:

- Develop a strategic plan for germplasm collections that addresses customer (user) needs.
- Build on a strong international collaborator network and establish new international linkages.
- Develop and implement a strategy for ARS to assume the leadership role in safeguarding critical genetic/genomic collections in plants, microbes and insects.

Problem Area I.b: Conserving Genetic Resources

Panel Rating: high impact

This represents the storage piece of USDA-ARS' germplasm collections. The panel applauds the agencies efforts to bring new facilities on line to address the growing needs of germplasm collections. During the past five years, ARS has added facilities in Ohio (ornamental plants), Alaska (arctic plants), and California (arid land plants). The number of accessions in the collections has increased, as have the number of duplicate samples, which is critical to the protection of this valuable resource. The panel expressed some concern over the limited microbial collections, but recognized some of this might be addressed through NP303. We would caution the agency against relying solely on ATCC for these collections based on the experiences of many users. While it was very apparent to the panel that ARS is doing an excellent job in conserving genetic resources in major crops, the panel would point to the need to address the serious shortfalls in collections of many minor crops species. Certainly, we recognize the limitation in resources that play in to these decisions.

Recommendations:

- Develop a strategic plan to insure that germplasm facilities are aligned with the germplasm conservation goals of the agency.
- Develop and implement strategies to insure the health and safety of accessions in the collections, particularly in cases where seed-born diseases are a threat.
- Insure genetic integrity of collections, particularly in cross-pollinated species.

Problem Area I.c: Documenting and Characterizing Genetic Resources

Panel Rating: low impact

While the agency recognizes the need to continually document the genetic resources in the collections and make this information available to the key stakeholders in the user community it has fallen short of this goal. To that end, USDA-ARS has developed GRIN (Germplasm Resources Information Network) as a computer-based interface to the collections. While this system was at the cutting-edge of information technology when developed over two decades ago, it now struggles to meet the needs of the user

community. This system appears to be built on an outdated platform with limited potential to interface with other emerging germplasm and genome databases. Another major limitation is the lack of updates on the characterization of the accessions within the collection. The addition of photographs documenting the accessions within the collections has proven to be a valuable addition to GRIN.

Recommendations:

- Develop an advisory group composed of GRIN users and stakeholders to prioritize the needs of the “next generation” of USDA-ARS’ germplasm collection database information network.
- Work towards a replacement of GRIN that ensures compatibility with other emerging genetic databases.

Problem Area I.d: Expanding Germplasm Evaluations and Characterization

Panel Rating: medium impact

The usefulness of any germplasm collection depends on its genetic integrity and characterization of accessions. Increasingly, molecular tools are paramount to the characterization of germplasm within the collections. All USDA-ARS germplasm facilities should have access to molecular analytical tools, and have staff trained to use these tools for the evaluation of germplasm. The panel applauds USDA-ARS’ efforts to equip these facilities and encourages the agency to complete this task.

USDA-ARS has the unique responsibility as curators of these germplasm collections to evaluate the accessions for genetic integrity and health, and certify these conditions to the user community. Further characterization beyond this is best done in partnership with the user community. The panel was very pleased to see that 150 evaluation projects had been supported by ARS during the period under review. We would encourage expansion of this effort in the future.

We were particularly pleased to learn of ARS’ efforts to partner with other organizations to address emerging threats to crop plants. The example of stem rust as a global threat to wheat is a great example of the leadership role ARS can, and should play in addressing these emerging diseases. The agency is in a unique position to bring together all of the public germplasm resources to evaluate this material for genetic resistance to emerging diseases. We would urge USDA-ARS to continue to take the lead in dealing with the search for resistance to emerging pests in collaboration with national and international collaborators.

Recommendations:

- Expand molecular evaluation capabilities in each of the germplasm facilities and projects.

- Expand collaborative “characterization” projects of accessions held within USDA-ARS collections through cooperative agreements.
- Work to insure genetic integrity of all accessions within the collections with a focus on out-crossing populations.

Problem Area I.e: Technology Transfer

Panel Rating: high impact

The panel recognizes USDA-ARS’ outstanding efforts to distribute germplasm to the broad user community. These collections represent a national treasure that needs to be put to use for agriculture and it is clear that the agency takes this task to heart. The panel would encourage USDA-ARS to refer to this as “germplasm distribution” as it does not represent technology transfer in the current sense of the meaning.

RESEARCH COMPONENT II: GENETIC CHARACTERIZATION AND GENETIC IMPROVEMENT

Genetic characterization and improvement of crops and organisms of significance to crop productivity comprises a larger portion of projects within NP301. The panel was pleased to see the diversity of crops and problems being addressed by USDA-ARS under this research component. In many cases, ARS scientists represent the lead group nationally in the improvement of crops represented in this program. This is particularly true for many minor crop species. It is important to note that often research represented in this component is not unique to the mission of USDA-ARS and to that end continued collaborations with other scientists is of critical importance to the Agency. Panel ratings for problem areas within this component ranged from low to high. In some cases, the panel felt that USDA-ARS had an opportunity to be national and international leaders in research problem areas, but had not yet reached this level of preeminence. In other areas, it is quite clear that ARS is leading the way in fields of science related to genetic characterization and improvement. The agency is encouraged to develop clear strategic goals and avoid redundancy with other research organizations in these research fields. Specific recommendations follow in each of the problem areas.

Problem Area II.a.1: Tools for Genetic/Genome Analysis

Panel Rating: medium-high impact

The development of tools to analyze genetic and genomic resources is of critical importance to crop improvement. While this represents a significant component to NP301, the panel recognizes that this is not the exclusive purview of USDA-ARS. Indeed, competitive funding from the National Science Foundation for plant genomics has made the development of these tools a national priority for public research scientists

nationwide. Having said that, the panel recognizes the critical role USDA-ARS scientists have played in this area, often providing national leadership in the development of genetic/genomic tools for a number of species. The panel would point to soybean as a prime example of this.

Recommendations:

- Identify key areas where USDA-ARS is best positioned to lead in the development of genetic tools. These might include crops species that are underserved by the private sector and the Land Grant University research community, and under funded by competitive grants from USDA-NRI and NSF.
- Work to avoid redundancy with other public research programs, and to a lesser extent the private sector.

Problem Area II.a.2: Special Research Populations and/or Genetic Stocks

Panel Rating: medium impact

The development of special research populations and/or genetic stocks is of significant importance to the long term ability to improve crop species. The panel recognizes that these efforts often lead to more rapid advances in germplasm improvement and plant breeding. The panel regarded this area to be a tremendous opportunity for ARS to play a critical leadership role that is arguably unique to their mission. This problem area is often not conducive to short-term funding through competitive grants and therefore could be seen as incompatible with the university-based research community. In spite of this opportunity, the panel did not see evidence in the accomplishment report that USDA-ARS had made a significant impact in this area beyond a few very compelling examples.

Recommendations:

- Encourage ARS NP301 leaders and scientists to elevate this as a priority area in future plans of work.
- Work to identify key gaps in special research collections and genetic stocks through careful analysis of existing populations and a careful survey of the research community.
- Develop and implement a strategic plan for the development of new special research collections. Include in this plan a mechanism to assess the impact of these collections on the improvement of germplasm.

Problem Area II.a.3: Genetic Determinants of Important Traits

Panel rating: medium impact

The elucidation of genetic determinants of important traits is a significant challenge facing crop improvement. The completion of genome sequences for various crop species, along with the development of genetic tools are opening the door to discovery of important genetic determinants of yield, biotic stress resistance, abiotic stress resistance and nutritional traits. The panel is well aware of many examples where ARS scientists have led the way in this important problem area, but felt the accomplishment report failed to document these examples. Of particular concern was the lack of focus and limited relevancy of trait discovery research in minor crop species. The agency is encouraged to consider commercialization plans for genetic discoveries that have the potential to benefit production agriculture. Regulatory hurdles would likely mandate that this be accomplished through partnerships with the private sector.

Recommendations:

- Develop a mechanism to document key contributions of ARS scientists in gene and genetic determinant discovery. This should include a clear tie to crop improvement goals of the agency.
- Develop a process to focus genetic discovery research in minor crop species on industry needs. This should include industry and research advisory groups that help to identify targets and set milestones for projects within this problem area.

Problem Area II.a.4: Genetic Marker Systems

Panel reported under II.a.1.

Problem Areas II.a.5 and II.a.6: Genome Characterization/mapping

Panel Rating: medium-high impact

The panel recognized the outstanding research of many ARS molecular biologists in these areas. This was largely based on individual knowledge of the contributions as the accomplishment report did not adequately address the impact in this problem area. The report was silent on the topic of commercialization strategies for products coming out of this work, which will likely require partners from the private sector to bring them to market.

Recommendations:

- USDA-ARS needs to articulate a clear goal for genome characterization research in terms of its support of, and tie to crop improvement. This should include a plan for commercialization of traits/improved crops through technology transfer strategies.

Problem Area II.a.7: Expansion of Genetic/Genomic Database Resources using Model Species

Panel Rating: medium impact

The expansion of genetic and genomic databases is growing at an exponential rate. USDA-ARS scientists have contributed to this growth through the discovery of, and contribution to important databases. Like a number of other problem areas within this research component, this is not unique to ARS. The panel rating reflects knowledge that panel members have of the key contributions ARS scientists have made to important databases. One excellent example of this is soybean. The accomplish report did not adequately address these accomplishments in the opinion of the panel.

Recommendations:

- USDA-ARS should consider where it has a unique opportunity, and perhaps a unique responsibility to lead the expansion of genetic/genomic databases. These should become a priority for the future.

Problem Area II.a.8: Advances in Genetic/Genomic Theory

Panel Rating: high impact

The panel recognized the critical need to continue the basic research that advances genetic and genomic theory. While this represents a minor area in research component II, it is an area in the opinion of the panel where ARS has shown outstanding impact. Some of the highest impact publications by ARS scientists fall under this problem area. Also, this panel regards this problem area as being a place where ARS is poised to make significant contributions to science, particularly through their work on recalcitrant species that often are not well funded through extramural grants.

Recommendation:

- Continue strong support for basic research in genetic and genomic theory, with a focus in areas that are often under investigated including minor crop species.

Problem Area II.b.1: Genetic Improvement: Release of Superior Genetic Resources

Panel Rating: high impact

USDA-ARS scientists have contributed greatly to the improvement of crops through the release of germplasm and new varieties. The panel was provided with a list of these releases, which upon review was quite impressive. USDA-ARS is to be commended for outstanding collaborations with university scientists and international research agencies

in the development of, and sharing of germplasm. Scientists within the agency work on a large variety of crop species and in many cases represent the only public research organization conducting genetic improvement studies with a particular species.

Recommendations:

- The agency should continue its efforts to support genetic improvement with particular attention being paid to those underserved species.
- National program staff and ARS scientists should work with outside organizations to capture usage data on material released, including germplasm early in development as well as finished varieties. This could become part of the materials transfer agreement or licensing agreements with outside organizations.

Problem Area II.b.2: Capitalizing on Untapped Genetic Diversity in Crop Improvement

Panel Rating: medium-high impact

This problem area is highly dependent on the success of research component I (Genetic Resource Management). The panel applauds ARS' role in projects such as GEM, which seeks to bring new genetic diversity to the improvement of corn. At the same time, the panel expressed concern over the limited impact of ARS in certain crop species with little genetic diversity. This is an area where ARS can, and should play a facilitating role by working with many collaborators around the world, particularly given its leading role as the "curator" of genetic resources.

Recommendations:

- Develop and implement clear strategic goals in the identification and utilization of untapped genetic diversity for crop improvement. This should begin with the crop species and should include possible sources of diversity. The genetic diversity goals identified should then feed into research component I; specifically, the plan of work to identify and fill gaps in the collections.
- The Agency should clarify how it will work with the private sector in capitalizing on untapped genetic resources.
- USDA-ARS should develop MTA's that are flexible for cooperative projects with other public breeding programs in the U.S. and abroad.

Problem Area II.b.3: Genetic Mitigation of Abiotic and Biotic Stress

Panel Rating: medium-high

The improvement of plant resistance to both biotic and abiotic stresses is a significant challenge to agriculture. Plant diseases and pests, along with environmental and nutrient

stresses result in serious limitations to crop yield. Emerging plant diseases and invasive insect pests require continual efforts to improve inherent crop resistance. USDA-ARS is recognized as a world leader in the identification and development of genetic resistance to biotic stresses. The panel felt that overall the agency was not as aggressive in providing leadership to the development of resistance to abiotic stresses. A noted exception to this is the leadership ARS has provided in the area of metal tolerance in crop plants. Abiotic stresses will play an increasingly important role in limited crop productivity, particularly on marginal lands and as we experience significant shifts in climate.

Recommendations:

- Strengthen programs devoted to the genetic mitigation of abiotic stress, while continuing strong support for biotic stress resistance.
- Work to set priorities for crop improvement by species. Include industry advisory groups in the process. For biotic stresses of minor crops, consider utilizing EPA pesticide residue data to develop targets for improvement with an eye towards limiting inputs.
- Develop and implement projects that seek to improve crops for low input situations such as organic production.

Problem Area II.b.4: Genetic Improvement of Product Quality/Value

Panel Rating: medium impact

Nutritional traits, specialty processing traits and other traits conferring health benefits are important targets for the future. The panel recognizes ARS' commitment to work towards these goals and realizes this problem area is in the early stages of development. Therefore, we would expect a much strong list of accomplishments and impacts in future years.

Recommendations:

- The panel would caution the agency against following the various bandwagons in this area and focus on output traits that add clear value to the product.

Problem Area II.b.5: New Genetic Methods for Crop Enhancement

Panel Rating: low impact

Continued improvement in crops is dependent on advances in new genetic methodology. The panel felt that accomplishments in this problem area fell short of the opportunity USDA-ARS has to be a lead research organization. The accomplishment report seemed to be a collection of unrelated work that might well have been captured in other areas of

the document. The panel placed particular importance on the development of assays that assists plant breeders. This is critically important for the advancement of germplasm, particularly if these assays can be made cost effective.

Recommendations:

- Focus efforts on the development of assays that help in the evaluation and advancement of germplasm.

Problem Area II.b.6: Statistical Approaches to Optimizing Breeding Progress

Panel Rating: High

Statistics and quantitative genetics are critically important to the advancement of germplasm and improvement of crop species. While this area makes up a relatively small portion of the overall NP301, the consensus of the panel was that the impact of the investigators is high. The scientists working in this area are quite influential, reaching out to the broad scientific community.

Recommendations:

- We encourage ARS to continue to invest in this critically important area, which continues to place the agency in a leadership role in the scientific community.

RESEARCH COMPONENT III: GENOME DATABASES

The development and long-term stewardship of genome databases is of critical importance to the improvement of crops species. Many aspects of this research component are unique to USDA-ARS' mission and in the national interest of agriculture. While the problem areas represented within this research component are very recent additions to the NP301 portfolio, the panel was very encouraged by the agencies progress to date. We were encouraged to learn of the plans to hire a new national program leader in bioinformatics to replace Dr. Leland Ellis, who's leadership has been missed within the agency. We encourage the agency to continue to make this area a priority in an effort to keep the

Problem Area III.a: Long-term Stewardship of Genome Databases

Panel Rating: high impact

The long-term support of genome databases in crop species and related organisms is arguably a mission that is unique to USDA-ARS. The panel applauds the agencies efforts to make this a priority as data management and access to the data represents the

“new agriculture”. While this area is quite new, only having been brought under the NP301 during the past five year work cycle, scientists are making a real impact. In several cases, USDA-ARS has taken the lead in the development of, and support of very useful databases. Of particular note are the Legume Information System and GRAMENE. The panel noted that these databases show strong interconnectivity to other databases and function well in support of the user community. However, it was noted by several panelist that a number of databases supported by USDA did not function in a true interconnected and transparent way with other similar databases for related crop species. The panel recognizes that this problem area has evolved with the technology and as a result has a tendency to be a bit piece mill.

Recommendations:

- The Agency should take immediate action to replace the vacant position of national program leader in this important field. The successful candidate should be someone who keeps USDA-ARS and plant bioinformatics “at the table” with other agencies supporting genome databases.
- Form a genome database advisory committee composed of users and contributors to help USDA-ARS develop strategic plans for the development of, and support of critical agricultural databases.
- Utilize the Interagency Working Group as a mechanism to prioritize the commitments to long-term support for databases emerging out of projects funded by the National Science Foundation Plant Genome Program.
- Continue to improve usefulness of genome databases to the user community, particularly as it relates to interconnectivity between databases.

Problem Area III.b: Development of Interconnected/Interoperable Genome Databases

Panel Rating: medium impact

As stated in the previous section, the panel views the issue of interconnectivity between genome databases to be crucial. While we recognize that many of these databases have just begun to come on line, the current state of interconnectivity is not ideal for the user community. GRAMENE, for example, does not go across the grass species, and Grain Genes has similar limitations. These databases represent what appears to be tremendous duplication of effort.

Recommendations:

- Make interconnectivity a very high priority within research component III. This should involve the user community as the ultimate costumer of the data.

Problem Area III.c: Analyses of Genomic Data

Panel Rating: low impact

The development of new bioinformatics tools to analyze genomic data represents the fundamental science of bioinformatics. While we recognize the Agencies leadership in statistical genetics, the accomplish report does not speak to major impacts in this area of bioinformatics. The panel felt that innovation in this field is of critical importance and USDA-ARS needs to bolster its efforts to be leaders in the field. This is a very competitive field of science, with the best and brightest in very high demand. It is our assessment that USDA-ARS has the potential to be a very attractive employer to leaders in bioinformatics for a number of reasons. First, the agency is in a strong position to provide solid, long term support that is critical to maintain computing infrastructure. Second, USDA-ARS scientists are available to serve as collaborators.

Recommendations:

- USDA-ARS is encouraged to invest resources in this area to emerge as a scientific leader in bioinformatics, particularly related to the analysis of crop and related species genomes.
- Continue the long tradition of partnerships with university collaborators in genome analysis.
- Insure strong and tangible linkages back to research component II (crop improvement).