FY 2003 NP 302 Annual Report

Introduction

National Program 302, Plant Biological and Molecular Processes, includes much of the Agricultural Research Service's fundamental research with plants that is necessary for practical advance, but is too far upstream to provide direct solutions for specific agricultural problems. The research focuses on mechanistic understanding of specific plant processes and properties. The knowledge and tools developed can be used to improve functions and properties of crops. This program is divided into three components. The first is Analysis and Modification of Plant Genomes (functional genomics, focusing on the molecular end of the research spectrum). The second component, Biological Processes that Determine Plant Productivity and Quality, encompasses mechanisms of plant growth and development, photosynthesis, productivity, and environmental responses that relate molecular events and processes to attributes of the whole organism. The third component, Mechanisms of Plant Interactions with Other Organisms, includes research on plant defensive reactions to pests and pathogens; secondary metabolism and bioproducts; and interactions with beneficial organisms. Together, the results of the research approaches under this National Program provide a continuum of understanding of plant function from genes to phenotype (plant attributes and performance).

In June 2004, ARS convened a workshop at which customers and stakeholders provided to ARS scientists their feedback on accomplishments over the previous five years, and their thoughts for future directions of this program. At this workshop, a distinguished panel of four external reviewers, chaired by Dr. James Siedow of Duke University, provided a retrospective assessment of the prior five years. The panel and the stakeholders identified strengths of the existing program and some weaknesses to be addressed during the next cycle. Based on that feedback, the ARS scientists developed an outline of a new Action Plan to be written for the next 5-year cycle of research. This new Action Plan was written and posted by the end of the year.

In November 2004, a second workshop was held, at which ARS scientists developed plans to implement the recommendations of the assessment panel and the stakeholders. These plans will be the basis for projects to be peer-reviewed, through the ARS Office of Scientific Quality Review (OSQR), in 2005 and, if approved, initiated in 2006.

During 2004, there were many important discoveries and advances, some of which are described below. By no means do these selected accomplishments capture the important achievements of the entire research program. Instead, they highlight the type of activities carried out under this program and the type of benefits that result.

<u>Functional genomics to speed up corn improvement</u>. A major constraint for crop breeders is limited knowledge of which genes control valuable traits. To assist breeders, ARS researchers at Columbia, Missouri, have provided the majority of the molecular marker resources in the public sector for trait mapping in corn. More recently, the ARS

scientists at Columbia, Missouri, along with scientists at the University of Wisconsin and University of California, Irvine, have developed a new genomic approach to identify genes that control agronomic traits. *Impact: For the first time, this new method exploits corn genomic discoveries to facilitate more targeted, efficient corn improvement.*

New strategy to prevent spread of genes from genetically engineered crops. Scientists at the USDA-ARS Plant Gene Expression Center, Albany, California, have developed a strategy that will help prevent gene spread from genetically engineered crops. The revised strategy incorporates three site-specific recombination systems, one to insert the DNA precisely into the plant genome, a second to remove selectable markers (such as antibiotic resistance genes), and a third to remove transgenic DNA from pollen. *Impact: The three systems, when working together, will provide an unprecedented level of control over the potential environmental spread of transgenic DNA.*

Two major genes control low phytate content. In southern states, there are many large poultry and swine feeding facilities which are point sources of phosphorus pollution from livestock waste. Soybeans that are naturally low in phytate (a major cause of phosphorus in the animal waste) are a great advance for reducing pollution. ARS scientists at Raleigh, North Carolina, have led a cooperative project to develop high-yielding soybeans with low phytate content. When plants were grown with excess phosphorus, seed phytate concentrations in normal soybeans doubled whereas levels in the low phytate line remained constant. This result led to the discovery that two different genes control phytate concentration in soybean. *Impact: The new information makes it possible to devise efficient plant breeding methods to transfer the low-phytate genes to soybean varieties.*

Developing molecular markers to breed low linolenic acid soybeans. Genetic reduction of linolenic acid in soybean oil is a major step that enables the manufacture of more healthful foods with low levels of 'trans' fats, which are created when the linolenic acid is hydrogenated. ARS scientists in Columbia, Missouri have identified three mutant soybean genes that control linolenic acid production. Two of these genes also have mutations, bringing the total number to five mutant alleles. *Impact: This important new information enables the construction of very specific molecular markers that will allow plant breeders to select and breed soybeans with very low linolenic acid, so that trans fats will be greatly reduced in soybean cooking oil.*

Understanding cold and freezing tolerance of crops. Winterkill and cold temperatures are unpredictable and cause major damage to horticultural plants and field crops. ARS scientists at Lubbbock, Texas, have mapped a gene that is essential for signaling cold stress in plants. At Raleigh, North Carolina, ARS scientists have developed methods to isolate specialized cells in winter wheat seedlings that survive extreme freezing temperatures. Those cells can now be used to identify genes that confer freezing tolerance in winter wheat. With support of the USDA-CSREES, National Research Initiative, scientists at the University of California, Davis, and ARS scientists at Albany, California, have identified the "vernalization" gene, which ensures that wheat plants won't flower and form grain until the greatest danger of killer frosts has passed. The ARS scientists successfully inserted the gene into wheat plants to test its effect, proving the essential role of the gene in freezing protection. *Impact: The identification of these genes and development of methods to work with them portend more rapid genetic progress toward effective resistance.*

Improving efficiency of strawberry production. Excessive runner production weakens strawberry plants, reduces branch crown development and consequently yield, and is costly to manage. A multi-year field trial was carried out by scientists at the Beltsville Agricultural Research Center, Beltsville, Maryland, to determine the effects of the plant growth regulator Prohexadione-CA on runner and branch formation in the June-bearing cultivar Chandler' grown in a cold climate, annual hill system. Prohexidione-CA was effective in reducing fall runners and increasing branch crowns. *Impact: This growth regulator, which has registration to strawberry, should provide an environmentally benign chemical method for controlling runners and thus reducing labor costs.*

Oats and barley with health benefits. Considerable scientific evidence indicates that eating whole grains has health benefits. ARS scientists are characterizing these bioactive components in oats and barley and identifying the germplasm lines needed to increase levels of these beneficial compounds even more. ARS researchers at Madison, Wisconsin, screened over 1800 oat and barley lines for beta-glucan and antioxidant content. *Impact: This new information will be used by plant breeders to develop oats and barley with even higher levels of nutrition and disease prevention value.*

Improving heat tolerance of crop plants. Excessive temperature is a major factor limiting agriculture. In Phoenix, Arizona, USDA-ARS scientists provided strong evidence that rubisco activase, an enzyme of photosynthesis, is a key to heat sensitivity of plants. The research provides a specific target for genetic manipulation to improve heat tolerance. In Urbana, Illinois, ARS scientists have developed transformation systems that insert modified forms of rubisco activase into crop plants, with results suggesting that it is possible to improve photosynthesis by doing so. The Phoenix group has an agreement with a private-sector company to begin to utilize these findings. In addition, heat affects other plant functions. ARS scientists in Lubbock, Texas, have identified a novel gene in a model plant, Arabidopsis, that is essential for heat tolerance. *Impact: The dual discoveries are a starting point for breeding more heat tolerant crops.*