FY 2005 Annual Report, National Program 302

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. Following recommendations emerging from a customer/stakeholder workshop in 2004, the Action Plan for this National Program was rewritten and the components of the program were refocused. The first component is Functional Utilization of Plant Genomes: Translating Plant Genomics into Crop Improvement, with research aimed at bridging the gap between fundamental DNA-based science and the applications of that science for crop improvement. The second component, Biological Processes that Determine Plant Productivity and Quality, encompasses mechanisms of plant growth and development, disease resistance, photosynthesis, productivity, and environmental responses that relate molecular events and processes to attributes of the whole organism. It also includes research to identify and enhance nutritional quality of foods. The third component, Plant Biotechnology Risk Assessment, houses research of two types: identification and evaluation of possible unwanted environmental or genetic consequences of genetic engineering, and development of new technology to mitigate or eliminate unwanted consequences. In 2005, the latter type of research is predominant. New risk mitigation technology is intended to be made available to the public, so that it can be used without restriction by any researchers developing genetically engineered products.

The year 2005 marked the end of the first 5-year cycle of peer-reviewed research projects in National Program 302. The new Action Plan provided guidance for the development of new projects for the second 5-year cycle. The project plans were peer-reviewed by panels of distinguished outside scientists late in 2005; after final approval, the new projects will replace the previous ones beginning in 2006.

During 2005, 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.

Hypoallergenic soybean is a natural. Previously, ARS scientists at the Donald Danforth Center in St. Louis, Missouri, demonstrated how to remove the major human allergen in soybean (P34/Gly m Bd 30k) by genetic engineering. The same scientists, in collaboration with the Univeristy of Illinois, have now discovered two accessions of conventional soybean in the USDA soybean germplasm collection in which nature has accomplished the same feat by a natural deletion of the gene that encodes the allergen. This finding provides a basis for producing conventional soybeans with greatly reduced allergenicity, especially for uses where genetically enhanced soybeans are not accepted.

Work was initiated to breed this and other traits to improve the digestibility and nutritional value of soybean meal into elite germplasm.

Discovering genes that protect plants from desiccation. ARS scientists at Lubbock, Texas, established a desiccation tolerance EST collection and the bioinformatics tools required for the accompanying EST database. The ESTs and database have greatly enhanced our understanding of the genetic components associated with desiccation tolerance in plants. A comprehensive profile of gene expression associated with desiccation tolerance revealed new insights into the role of LEA proteins in cellular protection and provided numerous new candidates for dehydration tolerance genes that may enhance the drought tolerance capacity of U.S. crops.

Physiological and genetic responses to tomato spotted wilt virus. ARS scientists at Dawson, Georgia, in collaboration with the University of Florida, developed an innovative strategy for developing peanut germplasm that is resistant to the devastating impact of tomato spotted wilt virus (TSWV) infection. Physiological and genetic responses under heavy TSWV pressure showed that the physiological gas exchange and drought responses of TSWV-infected plants were correlated with specific gene expression products throughout the growing season. This finding will facilitate the improvement of production methods and breeding programs that increase the resistance of peanut to TSWV.

Removing unwanted transgenes from genetically engineered plants. New genetic technology is needed that allows the removal of unwanted transgenes after their usefulness is ended (for example, antibiotic resistance genes used as selectable markers). ARS scientists in Albany, California, have shown that recombination systems previously demonstrated in yeast also function efficiently in higher plants. This technology is intended to be put in the public domain and made available for general use, so that access to this advance in genetic engineering methods is available to all.

Sugar metabolism in corn. Enzymes that metabolize sugar affect the value of corn for food and non-food uses. The functional role of genes that encode invertase, a sugar metabolizing enzyme found in corn cell walls, has been determined by ARS researchers at Gainesville, Florida, in collaboration with researchers at the University of Florida. The scientists used biotechnology to examine the effects of eliminating genes for invertase. Results showed a pivotal role for these genes that can be exploited to enhance the use and competitiveness of corn.

Marking the genes that control soybean oil quality. Commercial production of soybeans with genetically reduced linolenic acid concentration provides the oil supply that fuels an industry-led drive to improve the nutritional quality of food products with low-trans isomer formulations and lower the use of hydrogenated soybean oil. ARS scientists at Columbia, Missouri, discovered that three genes control the level of linolenic acid in soybeans. The scientists have now developed molecular markers specific for the beneficial genetic mutations in two of these fatty acid desaturase genes (GmFAD3A and GmFAD3C). The use of these mutation-specific molecular markers to identify breeding lines homozygous for these alleles will expedite the development of elite soybean varieties with superior oil quality.

Health benefits of oats. Antioxidant compounds found in oats may have healthful benefits for specific cellular mechanisms. ARS researchers and collaborators at the University of Wisconsin have demonstrated that feeding an oat antioxidant, called avenanthramide, reduced exercise-induced inflammation in rats. Further research to characterize these oat antioxidants will provide consumers with new knowledge about the nutritional value of whole grains and enhance the use and value of oats.

Understanding genes that control plant architecture. Plant architecture genes control plant structure and effect important traits such as number of flowers, fruit size, and tree shape. ARS researchers at Albany, California, have cloned the *Ultrapetala* genes, which affect bloom formation, and determined that these genes are key players in determining plant architecture. The results can be applied to improve agriculturally important plants for many valuable traits from fruit size to developing fruit trees that are ideal for mechanical harvesting.

How plants develop resistance to herbicides. In cooperation with the company SePRO, ARS scientists at Oxford, Mississippi, determined the genetic basis for resistance of hydrilla (an aquatic invasive plant) to the herbicides flurideon, norflurazon, diflufenican, picolinafen, flurochloridone, beflubutamid, and flurtamone. The inheritance gene mutations governing the activity of PDS enzymes conferred cross-resistance to norflurazon and overall negative cross-resistance (hypersensitivity) to these PDS-inhibitor herbicides. Arabidopsis thaliana plants transformed with these mutated PDS genes from hydrilla had similar patterns of cross-resistance to the herbicides. These plants exhibited normal growth and development even after long-term exposure to herbicide.

New heat-tolerant cotton germplasm with excellent fiber quality. ARS, in conjunction with its partner Cotton Incorporated, released three improved lines of upland cotton to the public for use in breeding new varieties. For the first time, these lines combine some of the excellent fiber quality of Acala-type cottons with the heat tolerance of Delta-type cottons. They can be used as a resource for breeders attempting to improve fiber quality of mid-south and southeast cottons, as well as for breeders attempting to improve heat tolerance of Acala cottons for the western United States.