National Program 302 Plant Biological and Molecular Processes Annual Report

FY 2007

National Program 302, Plant Biological and Molecular Processes, includes much of the Agricultural Research Service's fundamental research with plants that is necessary to understand the biological principles for plant growth and development. The research focuses on mechanistic understanding of specific plant processes and properties. The knowledge and tools developed can be used in an integrated research approach to achieve practical improvements in the functions and properties of crops that address consumer concerns. The Action Plan for this National Program was rewritten in 2004 with stakeholder input to ensure that the components of the program were relevant to current needs of U.S. agriculture. 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.

The year 2007 marked the second year of the 5-year cycle of research performance for National Program 302. The Action Plan provided guidance for NP 302 projects that has led to many important scientific 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. Rather, they highlight the type of activities carried out under this program and the type of benefits that result.

Component I: Functional Utilization of Plant Genomes: Translating Plant Genomics into Crop Improvement

Problem Statement 1A: Advancing From Model Plants to Crop Plants

New discovery of how plants perceive and respond to light. All aspects of plant biology hinge on the plant's ability to perceive light. Because the phytochrome (phy) family (phyA to phyE) are the major light receptors for plants, understanding how they function in regulating gene expression, is crucial for crop improvement. Researchers at ARS, Albany, California, and at the University of California, Berkeley, have found, contrary to expectation based on previous data, that phyA is the dominant photoreceptor regulating rapidly-induced genes in response to red-light signals. This finding represents a major shift in thinking about the molecular basis of phytochrome-regulated gene expression and opens up new opportunities for manipulating this system for agronomic improvement of crop species.

Problem Statement 1B: Applying Genomics to Crop Improvement

Novel aluminum tolerance gene characterized from sorghum. In acid soils, toxic forms of aluminum (Al) are solubilized from clay minerals that damage root systems, greatly reducing crop yields. ARS researchers at Ithaca, New York, have isolated a novel aluminum tolerance gene. The gene encodes a citrate efflux transporter that mediates release of citric acid into the soil where it binds and detoxifies aluminum, so it does not damage the growing root tip. The significance of this discovery, also supported by the National Science Foundation, is that this aluminum tolerance gene can be exploited by plant breeders to improve crop yields on acid soils.

Protecting the nutritional value of broccoli. Broccoli contains bioactive organoselenium compounds associated with cancer protection. However, these beneficial compounds can be dissipated as broccoli matures or during post harvest storage by enzymes within broccoli tissue. ARS researchers at Ithaca, New York, have isolated a broccoli gene for an enzyme that converts bioactive organoselenium compounds in broccoli into volatile selenium compounds. Now that the gene has been identified plant scientists can block or silence the gene as a new strategy to insure that the nutritional and health benefits value of broccoli are maintained and provided to consumers.

Component II: Biological Processes that Determine Plant Productivity and Quality

Problem Statement 2A: Understanding Growth and Development

Genes identified within legume nodules that fix nitrogen from the air. All plants require nitrogen for growth. While many plants obtain nitrogen from fertilizer, legumes have bacteria in their root system that can make use of nitrogen from the air. Symbiotic nitrogen fixation within the root nodules is critical for legume crop growth but little is known about the genes affecting this process. ARS researchers at St. Paul, Minnesota, have assessed the expression of more than 500 genes in the nodules of a model legume, *Medicago truncatula*. Results revealed that more than 80 genes had enhanced expression in root nodules including one putative plant disease resistance gene (R). Identifying the genes involved is the first step in developing new strategies to improve nitrogen fixation and nitrogen assimilation in crop plants.

Problem Statement 2B: Understanding Plant Interactions with Their Environment

Improving the heat tolerance of plants. The rate of photosynthesis declines at moderately high temperatures in temperate plants including the model plant, Arabidopsis. The decline is due to deactivation of the enzyme, RUBISCO (ribulose-1,5-biphosphate carboxylase/oxygenase), the enzyme that catalyze the first major step in photosynthesis. At warmer temperatures there is reduced ability of an activase enzyme to activate RUBISCO. ARS researchers at Urbana, IL, have developed a more thermostable activase for Arabidopsis by inserting a portion of a more thermostable activase from tobacco. The initial results indicate that the rate of photosynthesis as measured by gas exchange is improved in the transgenic lines at moderately high temperatures and the recovery of photosynthesis is also better when the plants are returned to lower temperature. Plant scientists can use the information gained from this “proof of concept” experiments to further develop RUBISCO activase as a potential target to improve the temperature tolerance of crop plants.

Identification of genes associated with apple response to fire blight disease. Fire blight is a destructive disease of apple and pear trees that is estimated to cost the U.S. fruit industry over $100 million a year in crop losses and disease control. ARS researchers at Kearneysville, West Virginia, have used DNA technology to identify over 450 apple genes that respond in apple between 1 and 72 hours after challenge with the fire blight pathogen. The DNA sequence of these genes was deposited in a publicly accessible database to enable horticulturalists and plant breeders to develop new strategies for protection apple and pear trees from fire blight disease.

Molecular markers for use in protecting barley from Russian wheat aphids. Russian wheat aphids are reducing barley yields in the western U.S. ARS researchers have developed a barley germplasm line that has resistance against all Russian wheat aphid biotypes in the U.S., but integrating that resistance into regionally adapted barley varieties could require years of skilled plant breeding. ARS researchers at Fargo, North Dakota, have recently developed molecular markers for the aphid resistance gene. The molecular markers can now be used to speed up genetic selection and more rapidly deploy the resistance into multiple barley varieties with varied malting and animal feed uses.

Problem Statement 2C: Developing High-Value Products

Plant root hairs found to be natural herbicide factories. Sorghum plants compete with weeds by releasing chemicals that inhibit the growth of surrounding plants. The root hairs of sorghum can release a substantial amount of a natural herbicide called sorgoleone. ARS researchers at Stoneville, Mississippi, have determined that the key enzymes required for sorgholene biosynthesis are localized in the root hairs. This new information can be used by plant scientists to manipulate and enhance the production of natural herbicides in other crop plants.

Papaya gene identified that affects yellow and red fruit color associated with nutritional value. Depending on the cultivar, papaya fruit may be the yellow color of carotenoids or it may be the red color of lycopenes. Since carotenoids are the source of human vitamin A and lycopenes are antioxidants, there are nutritional and health benefits related to the color of papaya fruit flesh. ARS scientists at the U.S. Pacific Basin Agricultural Research Center, in collaboration with researchers from the Hawaii Agricultural Research Center, the University of Hawaii, and the University of Illinois isolated and

characterized a key gene regulating the carotenoid biosynthetic pathway.
This discovery can be exploited to better understand the genetic linkage between fruit color and fruit flesh firmness, a post-harvest characteristic important for shipping and handling. Thee gene can also be potentially used to improve the nutritional quality of papaya.
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Release of recombinant inbred lines of cotton will help plant breeders improve yield, fiber and useful agronomic traits. Plant breeders need new sources of germplasm to improve cotton. ARS researchers at Maricopa, Arizona, have developed and released 96 introgressed recombinant inbred lines of upland cotton. These germplasm lines are highly diverse and will provide new resources for identifying and improving yield, fiber, and agronomic traits.

Autumn fertilizer improves ornamental nursery plant quality. Efficiency of nitrogen uptake from soil applied fertilizers can be lower than 30% during production of nursery plants. Growers need to know the optimal time for fertilizer application. ARS scientists at Corvallis, OR, in collaboration with scientists from Mississippi State University and Oregon State University, determined that foliar application of urea in the autumn increased nitrogen status of container-grown deciduous and evergreen Rhododendron cultivars, improved plant growth, and decreased reliance on fertilizers the following spring. This information will aid producers of container-grown nursery crops to develop fertilizer management strategies that decrease fertilizer use and production costs, improve plant quality, and minimize N loss to the environment.

Type of fertilizer influences cold hardiness of nursery trees. Tip dieback and bud death in the spring that result from winter cold injury can decrease quality and growth of nursery trees. Although it is well known that application of nitrogen (N) fertilizer late in the growing season can decrease cold hardiness and increase the potential for cold injury to buds and stems, the specific relationships between plant N status, fertilizer formulations, and fertilizer application time have not been well investigated. ARS scientists at Corvallis, OR, in collaboration with Oregon State University and Washington State University, determined that the type of N fertilizer used during production of green ash *(Fraxinus pennsylvanica*) had a greater impact on cold hardiness of stems and buds than did the N status of the tree. These results suggest that different fertilizer formulations, not just rates, can impact cold hardiness. This information will aid producers of field-grown nursery crops to develop fertilizer management strategies that improve plant quality.

Nutrient uptake by grapevines. While grapevines are generally known to benefit from associations with arbuscular mycorrhizal fungi (AMF), it is not known to what extent this benefit is influenced by soil type or the origin of the fungi that colonizes roots. ARS researchers at Corvallis, OR, demonstrated that grapevines grown in a red hill soil were exceptionally dependent on AMF to supply enough phosphorus (P) for growth, while vines grown in a more fertile, valley soil can acquire enough P for normal vegetative growth without AMF. Grapevine growth response and P uptake was not better when a native fungus was compared to a nonnative fungus. Results indicate that grapevines planted on sites with red hill soils absolutely require AMF, but growers can be less concerned about AMF when planting vines in valley soils. The use of AMF that are native to a particular soil is not a critical factor for vine establishment. This information will aid wine grape growers and extension viticulturalists to develop soil management strategies that enhance mycorrhizal establishment and function in vineyard systems.

Component III: Plant Biotechnology Risk Assessment

Problem Statement 3A: Improving and Assessing Genetic Engineering Technology

Characterizing soybean allergens serves as the basis for reducing Soybean ranks among the eight most significant food allergens, but new biotechnology strategies offer the potential to minimize those allergens. Developing these new strategies first requires assessing the natural variation in allergen composition in soybean. ARS researchers at Beltsville, Maryland, have profiled the major soybean allergen proteins in 16 different types of soybeans. New transgenic lines with reduced allergen content can now be evaluated and compared with the natural variation found in soybean.

Problem Statement 3B: Interaction of Transgenic Plants with Their Environment

Transgene expression reduced. Some consumers have concerns about the presence of marker genes in transgenic plants. To address these concerns and to provide new tools for biotechnology, scientists in

Albany, CA have tested a number of prokaryotic recombinase systems for their ability to excise marker genes from plant chromosomes. They determined that the parA and Bxb1 recombinases can excise marker genes from the Arabidopsis genome. These systems will facilitate precise genome engineering of plants, thereby helping both the biotechnology industry to achieve more predictable results and addressing some concerns over genetically engineered crops.

Molecular markers to facilitate hybrid seed production. Hybrid seed production requires use of cytoplasmic male sterility. ARS researchers at Gainesville, Florida, have identified genes that cause cytoplasmic male sterility in sorghum, as well as molecular markers for genes that restore fertility. The markers will enable plant breeders to efficiently move the genes that restore fertility into important sorghum lines to evaluate the ease of use of alternative sources of cytoplasmic male sterility.