Annual Report of Accomplishments And Results

Agricultural Research Programs
Purdue University

Federal Fiscal Year 2005

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TABLE OF CONTENTS

Page

A. PLANNED PROGRAMS

GOAL 1. AN AGRICULTURAL PRODUCTION SYSTEM THAT IS HIGHLY COMPETITIVE IN THE GLOBAL ECONOMY

Overview: A viable crop, livestock, and natural resource system is essential for the success of the Indiana economy. In 2004 (the most recent year available), Indiana net farm income was $2.36 billion (about 1%) of Indiana's GDP. In addition, forest-based products represent another $ 9 billion annually to the Indiana economy. A recent Biocrossroads Report (www.biocrossroads.com/agreport.pdf) indicated that the wood products, grains, pork/beef, canning, and baking sectors account for 80% of the jobs and wages associated with Indiana's agricultural economy. The goals of the newly formed Indiana State Department of Agricultural include: 1) develop the Indiana hardwoods industry, 2) increase biofuel production and use, 3) expand the food processing sector, 4) double pork production, 5) increase diversity of production, 6) enhance regulatory coordination, and 7) increase the role of state government in farm and trade policy. (www.in.gov/isda)

For 2004 (the most recent year available), cash receipts for Indiana agriculture were $6.04 billion with 66% from crop sales and 34% from livestock sales. (www.nass.usda.gov/Statistics_by_State/Indiana/index.asp) In 2004, Indiana ranked ninth nationally in crop receipts. The 59,500 farms in Indiana represent 2.8% of all U.S. farms. In 2004, Indiana agricultural exports were estimated at $1.86 billion, about 3% of total U.S. agricultural exports. Despite being a relatively small state with only 1.6% of total U.S. cropland, in 2004, Indiana ranked second in processing tomatoes and ice cream production; third in soybeans; fourth in peppermint and total eggs produced; and fifth in corn, spearmint, cantaloupe fresh market, and hog production. The challenge for Indiana farmers is to adopt and manage agricultural production practices that are environmentally sound, yet allow them to remain competitive in a dynamic global economy. This is especially critical as Indiana attempts to double hog production over the next 20 years as outlined in the Indiana Department of Agriculture's Strategic Plan. In the 2005 crop year Indiana growers set near record crop yields, and the livestock sector enjoyed considerable economic success.

Indiana is a leader in the life sciences with increased public and private sector coordination and planning. One of the newest research buildings in Purdue University Discovery Park is dedicated to life science research. Biotechnology is providing a new frontier for agriculture, food, and forestry systems. To date, the genomes of many higher plants, microbes and insects are known. Several Purdue faculty are world-renowned experts in plant, animal, and insect genomics. Purdue University scientists are leading the way in genomics, proteomics, metabolomics, nanotechnology, and a state-of-the art hardwood genomics effort. In 2005, 26% of the field corn and 89% of the soybeans produced in Indiana were transgenic varieties. Purdue University researchers seek to understand and exploit the genetic basis for plant, animal, microbial and insect form and function. Fundamental and applied research in genomics, proteomics, molecular biology, and bioinformatics are the foundation for the development of value added/identity preserved products. Purdue University scientists are engaged in a wide array of genetic research including development of DNA vaccines for poultry and Arabidopsis gene function discovery. Such discoveries can help increase the profitability to farmers and the entire food value-chain by improving the productivity of crops and livestock, and adding value to agricultural products.

Plant productivity is challenged by numerous biological and non-biological stresses. Purdue University is making a significant investment in research to mitigate the impact of potential economic losses from pests and plant stress. Several multidisciplinary teams of scientists are studying pests, such as the Western corn rootworm which has recently adapted and evolved to counter crop rotation as a biological control strategy, thus resulting in damage in first-year corn. Invasive species periodically enter our agricultural system. The soybean aphid, first discovered in Indiana in 2000, is becoming a major pest in northern Indiana. Purdue University researchers are exploring a variety of approaches to reduce potential pest losses including genetic resistance to pests, insect management on an areawide versus single field basis, biological control, and fewer chemical treatments by following Integrated

Pest Management strategies. In 2005, appliedresearch and extension experts conducted educational programs with growers on alternatives to combat soybean rust.

The 1996 Food Quality Protection Act has resulted in the cancellation of pesticides important in agricultural production. Also, public opinion on the use of transgenic methods to create plants that resist pests has placed new constraints on pest management. Purdue University scientists have been successful in several key pest management arenas, for example, the biological and economic implications of the suppression of the Western corn rootworm variant, evaluation of apples with resistance to a primary pathogen (scab), genetically improved wheat varieties to control the yellow barley dwarf disease, biological control of soybean aphids, and non-pesticide alternatives to manage stored grain.

The challenge of ensuring the health and well being of animals, while maintaining maximum production remains important to Indiana producers. Purdue University researchers are working to ensure that livestock are raised under conditions that minimize diseases and stress, maximize productivity, reduce environmental pollution, and are managed in ways acceptable to consumers. Researchers are working to reduce excess nitrogen and phosphorus in animal manure and finding ways to improve the well-being of swine while making them more productive. Purdue University is leading a national air emissions research initiative in collaboration with the EPA to measure actual on-farm emission levels of ammonia, hydrogen sulfite, and particulates in order to establish science-based regulatory guidelines for livestock producers.

U.S. agriculture is challenged by a very competitive global economy. Major contributors to the globally competitive position of U.S. agriculture include the development of biotechnology, rapid international flow of capital, changes in business structure, international trade agreements, domestic agricultural and environmental policies, rapid advances in information systems, just-in-time transportation systems, and electronic marketing systems.

Evolution of business practices, market power by concentrated agribusiness firms, adoption of transgenic crops, and the emergence of precision farming technology have added yet another new dimension of complexity and opportunity for producers and agribusinesses. Purdue University researchers are engaged in studies on the socioeconomic impacts of state and federal policies as well as the evaluation of different tactics and strategies for producer and business enterprises in this emerging global economy.

Purdue University research is closely linked with various stakeholders and extension educators around the state. For example, the use of soy-diesel is increasing in Indiana, in part as a result of the research conducted at Purdue University, and our close collaboration with the Indiana Soybean Board. The Indiana Soybean Board not only funds applied research, but also has provided financial support for an endowed chair at Purdue University in soybean utilization. Research programs are also addressing ways to use carbohydrates and oilseeds to make industrial products, such as substitutes for petroleum-based polymers, bio-based fuels, or enhancing the nutritional quality of grains for livestock. Other researchers are looking for new uses of agricultural products and by-products as feed for livestock and fish.

Successes:

- New corn processing techniques can increase fiber content if breakfast cereals and other cereal food products to enhance the achievement of high fiber dietary goals
- Direct fed microbials are a potential replacement for sub-therapeutic antibiotics in swine diets.
- Beneficial insects can reduce mimosa webworms and other landscape pests.
- Apples can be grown in the Midwest but require additional labor and special attention to input use.
- Mechanical tree trimming can be reduced with the application of gibberellin synthesis inhibitors.

- A procedure was developed to extract high-quality messenger RNA that can result in black walnuts with higher quality sapwood in fewer years.
- Microfluidic devices will be powerful tools for bioanalysis and drug research.
- Molecular markers linked to the Hessian fly avirulence gene vH13 were discovered.
- Two new soft-red winter wheat varieties with resistance to Fusarium head blight were released.
- Two genes responsible for arsenic hyperaccumulation have been identified in the fern Ceratopteris richardii that could result in the remediation of contaminated soils.
- Genes responsible for phosphate deficiency in plants have been identified in Arabidopsis.
- The QTL that influences stinging behavior in Africanized domestic bees has been determined.
- Soybean aphid thresholds have been determined to maximizing control efficacy.
- Genes that confer negative cross-resistance in Drosophilia may lead to more effective insect control with less risk insect resistance.
- Nuclear transfer technology may increase the efficiency of the production of transgenic animals and offer human therapeutics as well.
- Better understanding of gene expression in muscle can result in improved meat quality.
- Results of a general equilibrium global trade model suggest that unless negotiating strategies are adjusted the World Trade Organization goals of trade liberalization and a reduction in world poverty will not be achieved.
- On-line magnetic resonance detection offers a rapid, non-distructive method to screen fruits and vegetables for quality traits.

Benefits:

- Estimated that costs of establishing refuges to transgenic corn are relatively small.
- Better corn planter maintenance and operation can improve stands and yields at minimal cost.
- Increased tillage intensity and utilization of fall management techniques can reduce horseweed by 30% or more.
- Estimates of total factor productivity for ruminant and non-ruminant animals offer a better understanding of future world meat supply/demand balances and U.S. meat export potential, especially to Asian countries.
- Understanding of the forces that control RNA folding has considerable importance for antisense treatment of retroviral diseases such as AIDS and cancer.
- Improved understanding of the approximately 2000 genes in the cell walls of etiolated maize coleoptiles.
- Increased cutting height can contribute to stubble C and N reserves in alfalfa.
- Production of transgenic corn in an underground cave controlled environment offers a feasible means of producing proteins for pharmaceutical applications without gene flow risks.
- A bioassay was developed to determine the efficacy of fungicide applications to golf courses.
- E. coli-derived phytase added to pig diets can reduce the excretion of phosphorus in hog manure.
- Increased feeder space and cage height can enhance layer wellbeing and egg production.
- A technique designed to determine the cause of diarrhea in dairy calves will result in proper treatment and potentially less use of antibiotics.
- Wiping shoes at international airports of passengers who had visited farms while out of the country with 1% Virkon S was found to be much more effective than the procedures currently being employed.
- About 16% of U.S. consumers would pay more for pork labeled as produced with specified humane and environmentally friendly methods.
- The marginal cost of carbon sequestration was found to range from $3.30 per ton for fallow land to $62.50 per ton for high-input farms.

- Unless consumers make informed choices both full service and fast food restaurant food consumption can be less nutritious than food prepared and consumed at home.
- Specialty corn for masa flour will require a 3-5 cent per bushel premium.

State Assessment of Accomplishments:

Research at Purdue University continues to address the needs of various diverse stakeholders representing the entire value-chain from input suppliers to farmers to processors to retailers to the final consumers at home and abroad. Research spans a very broad base, including, developing animal diets to reduce adverse environmental impacts from waste; evaluating new technologies as tools for agricultural competitiveness; evaluating contractual and structural options for producer competitive positioning; increasing the efficiency of plant growth, and developing the base for value added products that have the potential benefits for consumers and producers.

Resources:

In 2005, approximately $ 3.81 million of Federal formula funds and $22.2 million state funds plus 219 FTEs have been invested in Goal 1. This is a best estimate and these are not presented as auditable numbers.

1A. Integrated and Sustainable Crop and Livestock Production Systems

Key Theme: Agricultural Profitability (1)

a. *Description:* Economic analysis of how farmers implemented non-Bt corn refuges showed that decisions were likely to be influenced by considerations other than cost; such as the logistics involved in segregation of genetically modified and non-genetically modified corn for marketing purposes. Analysis of international trading partners to accept genetically modified corn and soybeans showed that because domestic consumption of genetically modified corn was high (animal feed) there was little impact on current international markets. Also, it appeared that pricing differences between genetically modified and non-genetically modified crops were likely to be small, however, cost to segregate grain on-farm would increase. Analysis of the profitability of Bt corn as a means for controlling European corn borer in southwest Kansas and neighboring regions showed that unlike other regions of the Corn Belt (e.g., northern Indiana), the value of Bt corn for preventing yield losses substantially exceeded the technology cost. Field surveys of European corn borer larvae in Indiana corn fields indicated that the native European corn borer population and the associated risks of infestation continue to decrease statewide. This 'real-time' information was used to calculate current cost benefit tables for particular regions in Indiana. Multiple field test sites established in 2003 through 2005 to evaluate transgenic and non-transgenic solutions to managing European corn borer demonstrated nearly perfect crop resistance to European corn borer feeding injury while transgenic crop yields continued to improve relative to the existing tolerant hybrids.

b. *Impact:* The difference in costs associated with different Bt refuge configurations was small. Keeping genetically modified corn separate from non-genetically modified varieties may over-ride refuge configuration cost issues. This research underscored the fact that individual producers must examine their situation carefully -- base yields, the distribution of insect pressure, and market prices -- in making the decision whether to adopt Bt technology to control European corn borer.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Midwestern United States

Key Theme: Plant Production Efficiency (1)

a. *Description:* Establishing stand uniformity in maize is an intuitively important component for achieving the maximum yield potential in a given field in a given year. Uneven stands may be described in terms of plant-to-plant variability for spacing within the row, time of seedling emergence, and/or eventual growth and development. With the collaborative assistance of Case-IH engineers and agronomists, five sets of seed discs for use with a Case-IH 1200 ASM air planter were custom-engineered with distinctive patterns of seed cell positions that would create predictable planting patterns of crowded seeds and gaps. Field-scale trials were established at five locations throughout Indiana in 2005 to: 1) verify whether we could reliably create repeatable levels of plant spacing variability in large-scale field plots using custom-manufactured seed discs and a commercial-sized air planter, and 2) determine whether varying levels of plant spacing variability influenced maize grain yield in large-scale field plots planted to a single, aggressive, seeding rate. Results from a preliminary large-scale field research trial conducted in 2004 at a single location in northwest Indiana indicated that the custom-engineered planter seed discs did what they were designed to do; create repeatable treatment levels of plant spacing variability. The standard deviations of plant spacing for each targeted treatment level were very close to what was predicted at the onset of the trial. Results from the 2004 trial indicated that grain yields varied significantly with the greatest yields occurring with the more uniformly spaced treatments and lowest yields occurring with the least uniformly spaced treatments. A significant negative linear relationship was identified between maize grain yield and standard deviation of plant spacing in this trial that accounted for nearly 97% of the variability observed among treatment means for grain yield.

b. *Impact:* Uniform seeding is predominately influenced by the condition and operation of the planter. Better maintenance, repairs, and operation of the planter by the grower can easily correct problems of uneven plant spacing and, thus, improve yields of maize at minimal cost.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* U. S. Corn Belt

Key Theme: Plant Production Efficiency (2)

a. *Description:* Field experiments were conducted in 2003, 2004, and 2005 to evaluate the effect of giant ragweed removal timing and nitrogen fertility regime on weed and corn growth parameters, nitrogen accumulation, and crop yield. Tissue samples and yield data from 2003 and 2004 have been analyzed and 2005 tissue samples are currently being analyzed. Field surveys and small plot experiments have been conducted throughout Indiana to monitor the distribution of glyphosate-resistant horseweed and evaluate various control methods.

b. *Impact:* **P**reliminary work has shown that weeds are capable of absorbing over 25% of the available soil nitrogen if not removed in a timely manner. In addition, early-season tissue analysis of the nitrogen content of weed biomass indicates that corn yields are reduced if weeds were allowed to accumulate 10 pounds per acre or more of nitrogen. The control of insect-infested giant ragweed plants is reduced in direct relationship with the amount if tunneling in the plant, but can be improved by altering specific spray application factors. Glyphosate resistant horseweed is present in 28 counties in Indiana. Its prevalence is mostly associated with no-till cropping systems and in fields with wheat or soybean as the previous crop. The amount of glyphosate tolerance in selected populations ranges from 2 to 12 times the labeled rate. Current weed management programs are not providing adequate control of horseweed in 28% of southeast Indiana soybean fields. Increased tillage intensity and utilization of fall management tactics can reduce the prevalence of horseweed by 30% or more.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Eastern Corn Belt

Key Theme: Animal Production Efficiency (1)

a. *Description:* Some people are concerned about excessive use of antibiotics in livestock feed. Weanling pigs (n=180) were used in a 5-week experiment to investigate the effects of administering a bolus dose of direct fed microbials at weaning and/or supplementing the feed with direct fed microbials on growth performance and gastrointestinal morphology and physiology. Treatments included: 1) control with no supplementation of direct fed microbials or antibiotics, 2) Treatment 1 plus direct fed microbials administered in a bolus dose at weaning, 3) Treatment 1 plus direct fed microbials administered through the feed for d 1-35, 4) Treatment 1 plus direct fed microbials administered in a bolus dose at weaning, and through the feed for d 1-35, and 5) Treatment 1 plus in feed antibiotics. Overall, there was no effect of treatment on average daily gain. Including antibiotics in the diet improved average daily gain during phase 3 compared to pigs fed the control diet. Administering a bolus dose of direct fed microbials to pigs at weaning with or without subsequent provision of direct fed microbials in the feed resulted in similar growth performance to pigs. However, providing direct fed microbials in the feed alone, resulted in a reduced average daily gain during phases 1 and 2 compared to pigs fed the antibiotic diet. Overall, feed intake was higher for pigs fed the antibiotic diet compared to pigs fed the control diet, and compared to pigs given a bolus of direct fed microbials at weaning. Pigs provided a bolus dose of direct fed microbials at weaning and provided subsequent direct fed microbials in the feed had similar feed intakes to pigs fed the antibiotic diet.

b. *Impact:* Direct fed microbials are a potential replacement for sub-therapeutic antibiotics in swine diets. This study found no overall significant effects of direct fed microbials or their mode of administration on growth rate. Responses to direct fed microbials in this experiment were relatively small as was the response to in-feed antibiotics. However, even with minimal performance responses there were indications that direct fed microbials and antibiotics may alter gut morphology and possibly the active transport rates of nutrients by the gastrointestinal tract.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

Key Theme: Animal Health (1)

a. *Description:* New methods of determining best practices for measuring the physiological outcome of stressors to neonatal dairy calves were investigated by use of experimental infection of calves with Somalia dublin bacteria or by treatment with anabolic or catabolic hormones. These treatments allowed creation of disease models that can be used to test efficacy of potential treatments to ameliorate naturally occurring disease in this population of a naturally susceptible species. Measurement of body temperature through monitoring tympanic temperature of calves was able to closely track elevated temperature of infected animals. Behaviors and production measures were recorded for prepartum and postpartum cows fed diets that were designed to improve intake of dry matter. Investigation of temporal eating behavior with total dry matter intake of lactating first calf heifers was compared to the same behaviors in multiparus cows.

b. *Impact:* Contractual raising of dairy heifers and movement of animals between sites during the rearing period is becoming very common among dairies in the United States. Understanding effects of shipping stress and development of supplementation, and management strategies to ameliorate shipping stress has a

great influence on the profitability of calf rearing operations and on welfare of cattle in the receiving milking herd. The feeding of ascorbic acid and beta-glucan products is currently receiving much attention in academics, at the USDA, and from industry. Animal Feed Compositions and Methods of Using the Same, U.S. Patent No.6,939,864 was issued September 6, 2005. This patent was filed for Eicher-Johnson-McKee by Purdue Research Foundation for use of findings resulting from NC-1119 research.

c. Source of Federal Funds: Animal Health

d. Scope of Impact: United States

Key Theme: Organic Agriculture (1)

a. Description: Organically approved 0.5% cytokinin is a class of plant hormone for chemical thinning of apples. Applications were made at 50 and 75 ppm at petal fall and at 10mm fruit size. The applications of cytokinin had no effect on crop load or fruit size in either study. It appears unlikely that cytokinin will be an effective fruit-thinning agent. Efforts to control plum curculio with kaolin were only moderately effective. Better results were achieved with cultural methods, such as picking up dropped apples. Field trials were conducted using organic products for control of apple scab, sooty blotch and flyspeck. Calcium soap (CaC8) and calcium soap with sulfur showed very poor efficacy in the control of all three diseases. There were no significant differences between the calcium soap products and untreated fruit. In large-scale organic apple plantings, attempts to control weeds with organic herbicides proved unsuccessful. The combination of weed mats and tree mulch has provided favorable weed control, which has allowed the organic trees to improve their growth rates, although they still lag behind the conventional trees. The only major weed not controlled is thistle. Applications of neem to young trees have proven to be a fairly successful method for avoiding injury from Japanese beetles. 2003 was the first year with commercial levels of fruit production in the Gold Rush plots. Conventional trees averaged 62.2 fruit per tree, totaling 22.3 pounds of fruit per tree, for an average fruit weight of 0.36 pounds per fruit. The organic trees averaged 3.0 fruit, 1.0 pounds, and 0.33 pounds per fruit. The values from the conventional trees were significantly higher than from the organic trees for each of the three variables. These differences are the result of poor weed control early in the tree growth. Although yields in both treatments were relatively low, harvest data in 2004 showed significantly higher yields in the conventional Pristine trees. In the GoldRush apples, conventional trees averaged 111.7 fruit per tree, 36.1 pounds of fruit per tree and an average fruit weight of 0.33 pounds compared to 52.7 fruit, 16.2 pounds, and an average fruit weight of 0.31 pounds in the organic trees. 2005 was the first year that attempts were made to produce quality fruit. In the Pristine plots, conventional trees averaged 28.4 total fruit per tree and 9.9 pounds of fruit per tree compared to 4.9 fruit and 9.9 pounds in the organic trees. The conventional trees averaged a significantly higher cull rate than the organic trees, 64.5% to 55.0%. The major factors resulting in culls for the conventional trees were cracking and insects, primarily Japanese beetles and plum curculio. The primary cull factors for the organic trees were small size, poor shape and insects, primarily plum curculio. Culls due to disease were significantly higher in the conventional trees than in the organic trees. Fruit size was higher in conventional trees, but among marketable fruit, organic trees produced larger fruit. This was largely because the larger conventional fruit cracked and were rejected as culls.

b. Impact: **A**pples can be produced organically in the Midwest. However, an important consideration at the beginning of the process is to select trees that are resistant to apple scab. This decision will eliminate most of the disease concerns. Early in the establishment of an organic orchard, weed control is very important. Failure to control weeds will result in poor tree growth and a delay in fruit production. Because it takes about four years to get trees into production, organic growers may want to consider using synthetic herbicides to get their trees established. There would still be plenty of time (four years) to achieve organic certification before fruit would be harvested. Hand thinning appears to be the only viable method of

thinning organic apples. Insect control can be achieved using a combination of cultural practices and several organically approved insecticides. While the results of this study have not yet been analyzed for economic viability, it appears that it is feasible to grow apples organically in the Midwest with a reasonable amount of inputs.

c. Source of Federal Funds: Hatch

d. Scope of Impact: Midwest

Key Theme: Ornamental/Green Agriculture (1)

a. Description: The response of trees to the gibberellin synthesis inhibitors paclobutrazol and flurprimidol were investigated. Both compounds are effective in reducing the growth in length of shoots by 40 to 60%. In addition to shoot growth suppression, other benefits to tree health or tree responses valuable for tree care and maintenance occur. Both of these compounds reduce fungal disease infection and improve tolerance to drought and other adverse environmental conditions. Cambial growth also is reduced as in the growth of callus over wounds in the bark and those resulting from pruning branches. These growth inhibitors are known to bind to the protoheme iron of cytochrome P450 dependent enzymes in the isoprenoid pathway, inhibiting the production of gibberellin plant hormone, which controls the elongation of cells. Another mode of action for the growth reduction response in plants treated with paclobutrazol or flurprimidol could be an effect on electron transport in mitochondria. First, mitochondria were isolated from plant cells and exposed to a range of concentrations of growth retardants in vitro. Reduction of electron transport at high concentrations and stimulation at low concentrations occurred. Subsequently, experiments were designed to determine if the same response would occur if the mitochondria were exposed to paclobutrazol and flurprimidol in vivo. Mature European black alder (Alnus glutinosa) and silver maple (Acer saccharinum) were treated with paclobutrazol and flurprimidol using standard methods in the spring before bud opening. Seeds produced by the silver maple trees were collected at the end of the first and second growing seasons and grown in the greenhouse. Mitochondria were isolated from the leaves of the mature trees and seedlings one and two growing seasons after treatment. Electron transport in the mitochondria as evident by NADH oxidation and cytochrome reduction was determined. Paclobutrazol reduced whole chain electron transport in mitochondria of European black alder by reducing the oxidation of NADH and reduction of cytochrome c by 12 and 29%, respectively. Electron transport in mitochondria of seedlings grown from seeds collected from treated silver maple trees the first year following treatment was stimulated. The second year after treatment of the parent trees, electron transport was not affected This is the first report of a growth retardant affecting electron transport in plant mitochondria exposed to the compounds in vivo and of carryover of the response to the progeny of treated trees.

b. Impact: Trees and shrubs often grow too large for the available space in urban areas. In the past, costly mechanical trimming was the sole method available to arborists and utility foresters to reduce tree and shrub size. Consequently, beginning in the 1950s, research on chemical growth retardants was initiated to develop an alternative approach to limiting size and growth rate of trees, particularly for trees under electric distribution wires. Today the electric industry is using the third generation of chemical substances and application methods to manage tree growth in utility rights-of-way. Satisfactory performance of the compound paclobutrazol as a growth retardant, as well as several benefits to tree health revealed through recent research, has spurred an active expansion of the market for this growth retardant to commercial landscape and general urban tree care. A mode of action for growth retardants involving the inhibition of gibberellin synthesis, which reduces the elongation of cells, has been known for a long time. This research demonstrates for the first time another mode of action involving interference with the so called electron transport chain in cell organelles called mitochondria.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

Key Theme: Ornamental/Green Agriculture (2)

a. *Description:* Single and multiple linear regression techniques were used to explain the capacity of initial seedling root volume and first-order lateral roots relative to shoot height, diameter, and fresh mass to predict first and second-year field height and diameter for trees in southern Indiana. Initial diameter, height, and root volume were the most important morphological characteristics that predicted first-year field response for absolute height and diameter. Initial seedling root volume was a better predictor of field response than first-order lateral roots for both oak species, though not for cherry. Multiple-variable models accounted for a greater proportion of the total variation in seedling field height and diameter than did single-variable equations. Growth and nutritional response was tested for three hardwood tree species at six rates (0, 15, 30, 45, 60, and 75 grams) of polymer-coated controlled-release fertilizer applied to the root zone at outplanting in southern Indiana. Compared to non-fertilized seedlings, the 60 gram rate accelerated mean height and root-collar diameter growth by 52% and 33% in year-1 and 17% and 21% in year-2, suggesting that controlled-release fertilizer has potential to improve early establishment success of hardwood afforestation plantings.

b. *Impact:* Forestry is among the most economically important agricultural sectors in the Midwest. Identifying methods to improve hardwood seedling quality and silvicultural techniques at outplanting will help to improve reforestation success and forest productivity.

c. *Source of Federal Funds:* McIntire-Stennis

d. *Scope of Impact:* United States

Key Theme: Ornamental/Green Agriculture (3)

a. *Description:* A procedure was developed for extracting high-quality messenger RNA (mRNA) from the various cell types and tissues present in the stems of black walnut (Juglans nigra L.) trees (sapwood, heartwood, transition zone, and vascular cambium). This mRNA can be reverse-transcribed, enzymatically, to convert it into single-stranded complementary DNA (cDNA). The cDNA can then be labeled with fluorescent tags and hybridized to the appropriate genomic microarray in order to determine which genes were being expressed at the time the tree tissues were originally sampled. Although there are no walnut-specific microarrays available, there are microarray chips onto which more than 5,000 unique poplar (genus Populus) sequences, many of which are related to wood formation, have been spotted. Whether walnut cDNA is sufficiently homologous to the poplar sequences for them to hybridize is not yet known. Therefore, a preliminary study, using a limited number of cDNAs and four chips, was conducted in which it was demonstrated that there were no significant inter-species incompatibilities. A larger, follow-up experiment in which mRNA was extracted from the transition zone, sapwood and cambium of four walnut trees that were harvested at various times of the year was conducted. These mRNAs were converted to fluorescently labeled cDNAs that were hybridized in various combinations to 30 poplar microarray chips. These results will help us to identify genes that are involved in converting sapwood to heartwood.

b. *Impact:* Black walnut, an extremely valuable fine hardwood, has genetic variation in sapwood production that results in trees that have as few as three and as many as 20 annual rings of sapwood. The commercial value of black walnut is determined by its heartwood production; a decrease in the time it spends producing sapwood can result in shorter harvest cycles. For a veneer tree that is harvested when 60 years

old, reducing the period of sapwood production by 10 years would have a significant economic impact. Currently, it is possible to cause sapwood to take on the appearance of heartwood by steaming black walnut lumber. However, this treatment is labor-, equipment- and energy-intensive. There would be considerable savings if this step could be eliminated from the manufacturing process. Moreover, shortening rotations and reducing production costs will make more high-quality heartwood available at a lower price to the end-user. Ultimately, this will allow the furniture-making industry to be more competitive globally.

c. *Source of Federal Funds:* McIntyre-Stennis

d. *Scope of Impact:* United States

Key Theme: Agricultural Competitiveness (1)

a. *Description:* Over the past two decades there has been a marked shift in the composition of global food trade, away from grains and oilseeds and towards trade in meat products. Productivity growth could explain a portion of this change. However, until now, the measurement of total factor productivity at the subsector level has been frustrated by the inability to allocated agricultural inputs to different activities. Recent developments in productivity measurement spearheaded under this project now allow calculating total factor productivity growth at the sub-sector level without allocating all inputs to specific outputs. There are significant differences in productivity growth when agricultural productivity is disaggregated into crops, ruminants and non-ruminants. Developed countries have had greater productivity growth in crops and ruminant productivity than developing countries. However, developing countries show much higher rates of productivity growth in non-ruminant (pigs and poultry) production. In most of the countries non-ruminant growth has driven the increase in livestock productivity, with ruminant productivity lagging behind. The results indicate some degree of convergence between developing and developed countries in crops and non-ruminant production, but not for ruminant production. This has important implications for future food trade patterns, since these are driven by comparative advantage, and it is generally believed that the latter depends critically on total factor productivity growth.

b. *Impact:* Future total factor productivity growth in crops, ruminants and non-ruminants, world-wide, at the level of eight regions, taking into account both expected growth in the technology frontier and the catching up of developing countries to the existing frontier was forecast. The results predict an eventual slowing down of total factor productivity growth for world agriculture, as the developing countries approach the technology frontier. Relative to the last forty years, somewhat faster total factor productivity growth in non-ruminants (driven by high growth rates in the developing countries), and slower global total factor productivity growth for crops and ruminants is expected. While agricultural total factor productivity growth was dominated by the rich countries in the past four decades, it is the developing countries that will contribute the majority of global agricultural total factor productivity growth in next forty years.

c. *Source of Federal Funds:* Hatch and USDA- National Research Initiative

d. *Scope of Impact:* Global

1B. Genetic Resource Development

Key Theme: Biotechnology (1)

a. *Description:* Microfluidic devices and systems for single cell and single molecule sensing and analysis have been developed including a microfluidic technique for electroporation of bacterial and mammalian

cells based on continuous DC voltage on a microchip platform. A simple microfluidic device which lysed green fluorescent protein (GFP) expressing Escherichia coli cells under continuous DC voltage while cells flowed through was tested. The cell lysis only happened in a defined section of a microfluidic channel due to the local field amplification by geometric modification. Local field strength of 1000-1500V/cm was required for nearly 100% cell death. Cell lysis was witnessed by both plate count and fluorescence spectroscopy. The cell membrane was completely disintegrated in the lysis section of the microfluidic device, when the field strength was higher than 2000 V/cm. The devices were fabricated using low-cost soft lithography with channel widths considerably larger than the cell size to avoid clogging and ensure stable performance. This device was tested on mammalian cells such as CHO and HT-29 cells. The cells were flowing through the microfluidic channel under a pressure and cells passed the narrow section one by one. In the meantime, an electrical field was present between the two reservoirs. The size and the morphology of cells changed at the entrance of the narrow section when the field intensity was high enough. CHO cell diameter averagely expanded by about 9% when the electroporation field was 150 v/cm, about 27% when the field strength was 200 v/cm, and about 41% when the field strength was 300 v/cm. Such expansion in the size was due to osmosis when the cell membrane was breached. Similar phenomenon happened to HT-29 cells and the expansion was about 46% when the field intensity was 300 v/cm. Some change in the cell morphology can be seen in this case too. These are clear indications of electroporation. The electroporation of CHO cells started around 150-200 v/cm in our experiment. This tool will be ideal for high throughput cell lysis or permeabilization, which are important for biosensors and biomedical devices.

b. *Impact:* The microfluidic electroporation and force measurement techniques will be powerful tools for bioanalysis and gene/drug research. These tools may be used to genetically manipulate bacterial cells for improved understanding of virulence genes and pathogenesis. Such techniques will enable us to response to outbreaks caused by new bacterial strains in a timely fashion.

c. *Source of Federal Funds:* Hatch and National Science Foundation

d. *Scope of Impact:* United States

Key Theme: Biotechnology (2)

a. *Description:* A simple procedure to identify and isolate hairpin loop secondary structures in DNA and RNA that possess unusual stability (high and low) was developed. The procedure relies on enhanced migration of compact secondary structures in electrophoresis gels under native conditions relative to single strand random coils of the same chain-length and nucleotide composition. The extent of mobility enhancement of a hairpin structure is closely related to the overall thermodynamic stability of the molecule. This method has been used to fractionate relatively complex mixtures of hairpin structures differing only in the sequences of nucleotides contained in the loop portions of otherwise identical molecules. On simple electrophoresis gels the most stable structures migrate fastest followed by bands containing molecules of decreasing thermodynamic stability. The identity of the various molecules thus separated was then determined by MALDI-TOF mass spectrometry. This method was extensively tested on libraries of DNA hairpin structures containing loop of three and four nucleotides and currently is being used to survey for unusual stability hairpins containing larger loops. For example, this method was used to study an unusual DNA hairpin structure containing seven nucleotides in the loop and two base pairs in the stem region. In these studies a series of mini-libraries containing all four nucleotides at each position in the loop were analyzed by non-denaturing gel electrophoresis. Multiple bands were observed in most of the libraries. These bands were subjected to MALDI-TOF mass spectrometry to identify which nucleotide substitutions were present in the bands. This analysis has defined the loop positions and nucleotide sequences responsible for the unusual thermodynamic stability of this molecule. This information is currently being used in molecular modeling simulations in order to identify potential non-covalent

interactions between loop nucleotides which may account for the added thermodynamic stability of the overall structure

b. *Impact:* Understanding the forces that control RNA folding has considerable importance for antisense treatment of retroviral diseases such as AIDS and Cancer. Successful antisense treatment requires knowledge of the secondary structure of the target RNA molecule. Successful prediction of RNA secondary structures requires refinement of the programs and thermodynamic data used to predict secondary structures from nucleotide sequence. The goal of these studies to further understanding of the forces involved in forming secondary structures in both RNA and DNA.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

Key Theme: Biotechnology (3)

a. *Description:* Molecular genetic markers linked to Hessian fly avirulence gene vH13 were discovered. Markers 124 and 134, nearest the gene, were used to initiate chromosome walks in an effort to clone vH13. The 124-chromosome walk proceeded in both directions and covered over 1 Mb of the Hessian fly genome. The continuity of this walk was confirmed by both fluorescent in situ hybridization (FISH) and by fiber-FISH. The presence of repetitive elements and members of gene families made chromosome walking difficult. Further, a gap in the Hessian fly BAC libraries was encountered that stopped progress until a new BAC library was constructed, indicating that this region of the Hessian fly genome was resistant to cloning. Chromosome walking from marker 134 encompassed about 600 kb of Hessian fly genomic DNA, but suffered from similar difficulties. Together, these contigs represent about 5% of Hessian fly chromosome X2. BAC clones within contig-124 were used to calculate the correspondence between the physical distance and the genetic distance in the vicinity of vH13. These measurements indicated that 1 map unit (Kosambi centiMorgans) corresponds to less than 100 kb of genomic DNA. The ends of 40 BAC clones in walk-124 and 10 BAC clones in walk-134 have been sequenced. One BAC clone, Mde8i18, was completely sequenced. This sequencing generated over 24,000 bp of DNA sequence in 400 to 600 bp fragments that were positioned along the contigs. Genes within this sequence have been determined to have orthologous genes in the fruit fly (Drosophila melanogaster), and the malaria mosquito (Anopheles gambiae), and indicated that micro-synteny exists between all three species. An AFLP-based genetic map of the Hessian fly genome was constructed, and physically anchored to the Hessian fly polytene chromosomes. This map includes five avirulence genes: vH13 near the telomere on the short arm of chromosome X2, vH6 near the centromere on the long arm of chromosome X2, vH9 in the distal region on the long arm of chromosome X2, and both vH3 and vH5 located in the proximal region of chromosome A2. This map can be used to test for a genetic correspondence between candidate avirulence genes and mapped Hessian fly avirulence genes. Toward that effort, BAC clones that correspond to genes that are expressed in the first instar Hessian fly salivary gland and appear to encode secreted salivary gland proteins (SSGPs) have been physically positioned on this map by fluorescent in situ hybridization. Three BAC library of the Hessian fly genome were constructed during the investigation.

b. *Impact:* Improved Hessian fly genetics will enable avirulence gene cloning, and thereby provide greater knowledge of the molecular interactions between insects and their host plants, the physiology of insect gall formation, and the interactions among organisms that share gene-for-gene relationships. The contiguous genomic sequences (contigs) around vH13 will facilitate vH13 gene cloning, making vH13 the first avirulence gene cloned from an insect. The physically anchored genetic map of the Hessian fly will permit tests for the correspondence of candidate avirulence genes and lay the foundation for Hessian fly genome sequencing.

c. *Source of Federal Funds:* Hatch, USDA- Agricultural Research Service, and USDA-National Research Initiative

d. *Scope of Impact:* United States

Key Theme: Plant Germplasm (1)

a. *Description:* The two new soft red winter wheat cultivars, INW0411 and INW0412, performed very well in 2005 at multi-location tests in Indiana and in various out-of-state tests. INW0411 has low incidence and type II resistance to Fusarium head blight and INW0412 has type I and type II resistance to Fusarium head blight. Both cultivars have ranked in the top 10% of lines in regional tests for low Fusarium head blight index. Both cultivars proved to have excellent winter hardiness in tests at Lafayette, Indiana in 2004-2005, the first season resulting in significant winterkill since 1995-1996 in Indiana. Both cultivars have resistance to Stagonospora blotch, Septoria blotch, leaf rust, soilborne mosaic and powdery mildew; and INW0412 has resistance to stripe rust. Seed of both cultivars was available on a limited basis to seed growers in fall 2005. The yellow dwarf virus resistance of wheat cultivar INW0316 was very effective in tests in the southeast US in areas with severe yellow dwarf virus in 2005, and INW0316 performed at the top of tests. The two new oat cultivars, Woodburn and Robust showed excellent performance in 2005 in Indiana and in trials outside of Indiana. Woodburn is very early and has resistance to crown rust and yellow dwarf virus, and is particularly well adapted to northern Indiana, Illinois and Iowa. Robust has unusually strong straw, is three days later than Woodburn, has resistance to crown rust and yellow dwarf virus; and is well-adapted to northern Midwest areas and Ontario, Canada. This cultivar is expected to be grown on significant acreage in the midsouth and southeast. Low incidence to Fusarium head blight was mapped on chromosome 2B and close to DNA markers Xbarc200 and Xgwm210. A gene(s) for type II Fusarium head blight resistance was identified in a wheat line that has a portion of chromosome 7el2 from wheatgrass, and which complements Fusarium head blight resistance genes in wheat.

b. *Impact:* Wheat cultivars INW0411 and INW0412 are expected to be widely grown in the eastern United States because of their moderate resistance to Fusarium head blight, excellent winter hardiness, and resistance to other important diseases. INW0316 is being grown in the midsouth and southeast United States due to its outstanding resistance to yellow dwarf virus; it is the only variety available that has yellow dwarf virus resistance. Woodburn oat will be widely grown in northern Indiana, Illinois and Iowa due to its earliness and high yield. Robust oat will be grown in the northern Midwest and Ontario due to its outstanding straw strength, yield, and resistance to crown rust and yellow dwarf virus. The strong Fusarium head blight resistance of chromosome 7el2 of wheatgrass significantly increases partial resistance of wheat, and is expected to significantly enhance resistance to this important disease in future varieties. The durable gene Stb1 was mapped to chromosome 5B, near Xbarc74 and a newly developed SCAR marker; so that Stb1 can efficiently be pyramided with other septoria tritici blotch resistance genes in future wheat varieties.

c. *Source of Federal Funds:* Hatch and USDA-Agricultural Research Service

d. *Scope of Impact:* United States and Canada

Key Theme: Plant Germplasm (2)

a. *Description:* An array of transgenic crop varieties, including sorghum, are likely to be developed and deployed in the near future. This has stimulated interest in the study of the extent of natural gene flow between cultivated crops and their wild kin, particularly in the centers of crop origin. During the last two years, an extensive survey in the center of origin for sorghum, Ethiopia and also in Niger, West Africa has

been conducted. The natural outcrossing rate is variable among sorghum strains and varieties. Preferentially self pollinated, outcrossing rates among sorghums can reach 26% for a grain-type sorghum and 61% for an open grass-like panicle such as sudan grass. Gene flow has been observed between individuals that belong to different sorghum species and within or between gene pools. Outcrossing can also involve individuals with different ploidy levels. The survey determined that crop and wild relatives of sorghum are found in nature and often sympatrically and in many situations with synchrony in anthesis period.

b. *Impact:* The deployment of transgenic sorghums is likely to be met with trepidation primarily due to the concern that feral transgenic hybrid forms that are more difficult to eradicate may arise as a result of natural and accidental cross-pollination. Research is needed to assess the extent of spontaneous gene flow among the cultivated-wild-weed-complex of sorghum, and to devise means of mitigation if the results project possible danger.

c. *Source of Federal Funds:* Hatch and United States Agency for International Development

d. *Scope of Impact:* World

Key Theme: Plant Genomics (1)

a. *Description:* Dynamic changes in cell walls of etiolated maize coleoptiles, sampled at one-half-day intervals of growth, were analyzed by chemical and enzymatic assays, and Fourier transform infrared spectroscopy. Although infrared spectra of walls from embryonic, elongating, and senescing coleoptiles were broadly discriminated from each other by exploratory Principal Components Analysis. Neural network algorithms (both genetic and Kohonen) could correctly classify the ages of all individuals to their one-half-day interval of growth. Our results establish a paradigm for classification of a comprehensive range of cell wall architectures altered during development, by environmental perturbation, or by mutation. Fourier transform infrared spectra derived from sufficiently large populations of mutants of Arabidopsis also enabled training of artificial neural networks. Neural network algorithms are an appropriate and robust means to identify and classify novel cell wall phenotypes by comparison with a growing calibration set of characterized cell wall mutants. The mixed-linkage (1,3),(1,4)-beta-glucans are unique to the Poales, the taxonomic order that includes the cereal grasses. A cellulose synthase-like core catalytic domain of the (1,3),(1,4)-beta-glucan synthase, with the genes that encode them appear to be among those of the CESA/CSL gene super-family. A distinct glycosyl transferase also appears to be integral in the synthetic machinery to drive polymerization. Proteomic approaches were used to classify the extrinsic Golgi membrane-associated polypeptides, and viral-induced gene silencing to suppress expression of members of the CESA/CSL family to identify candidate genes that encode the core synthase.

b. *Impact:* It is estimated that over 2000 genes are involved in cell wall biogenesis during plant cell growth and differentiation. Plant cell walls are the primary raw materials used in the timber, textile and paper industries and provide a rich source of polymers for food products, films, thickeners and many other materials. Because cell walls are an important source of raw materials for multiple industries, it is anticipated that many cell wall biogenesis-related genes just now being identified and characterized will be of economic importance via genetic modification of cell wall characteristics in plants. Examples include the modification of pectin-cross-linking to increase shelf life of fruits and vegetables, the enhancement of dietary fiber contents of cereals, the improvement of yield and quality of fibers, and the relative allocation of carbon to wall biomass for biofuels. Plant cell-wall polysaccharides have been found to be important agents in the mitigation of human diseases, such as dietary fibers, immuno-stimulants and nanosurface modifying agents for medical devices.

c. *Source of Federal Funds:* Hatch, National Science Foundation, and Department of Energy

d. *Scope of Impact:* United States

Key Theme: Plant Genomics (2)

a. *Description:* Signaling molecules and genes in the fern Ceratopteris richardii that are necessary for sex determination and differentiation have been identified. Also identified are two genes in the fern Pteris vittata that allow it to hyperaccumulate and tolerate high levels of arsenic. One is an arsenic reductase and the other encodes a putative protein that is necessary to shuffle arsenic to the vacuole of the cell.

b. *Impact:* Understanding the genetic basis of arsenic hyperaccumulation in this extraordinary fern will be useful for the remediation of arsenic contaminated sites.

c. *Source of Federal Funds:* Hatch and Department of Energy

d. *Scope of Impact:* United States

Key Theme: Plant Genomics (3)

a. *Description:* The primary objectives of this project were to determine the roles of two plant RNA-dependent RNA polymerases (RDR1 and RDR6) in plant antiviral defense and RNA silencing. Transgenic Arabidopsis plants were constructed that express the virus-inducible RDR1 under control of an inducible promoter. Preliminary results suggest that upon induction of the RDR1, the transgenic plants become resistant to a strain of tobacco mosaic and to a strain of alfalfa mosaic virus. These results further indicate that the virus-induced RDR1 is involved in plant antiviral defense and may be utilized as a potential target of molecular manipulation for genetic engineering of plant resistance to viral pathogens.

b. *Impact:* Understanding the roles and mode of action of plant RNA-dependent RNA polymerases can help elucidate the molecular mechanisms of plant defense response against foreign and invasive agents such as viral pathogens.

c. *Source of Federal Funds:* Hatch and National Science Foundation

d. *Scope of Impact:* United States

Key Theme: Plant Genomics (4)

a. *Description:* Botrytis causes the gray mold diseases in many crop plants resulting in significant crop losses. The disease occurs under a wide array of conditions and spoils agricultural products after harvest since it can be active even at low temperatures. Botrytis and other necrotrophic infections differ from biotrophic infections in many ways. First, Botrytis promotes or benefits from host cell death during pathogenesis. Dead cells and necrotic tissues leak nutrients and provide saprophytic growth base from which Botrytis further colonizes healthy tissue. In contrast, biotrophic pathogens require living host cells to establish infection and complete their life cycle. Second, microbial necrotrophy is often accompanied by secretion of toxins into host tissues which often play a crucial role in pathogenesis. Defense responses triggered by various plant pathogens including Botrytis show a significant degree of overlap. However, the efficiency of defense responses in plant protection against different pathogens varies significantly. There is no evidence for monogenic resistance to Botrytis as has been observed for some necrotrophs that produce toxins or biotrophic pathogens involved in race-specific resistance. Key components of the biotrophic pathogen response pathways have been isolated or genetically defined. Many of these appear

to be components of the systemic acquired resistance (SAR) related pathways that regulate Salicylic acid dependent defense responses or R-gene based resistance. These pathways appear to have no significant role in resistance responses to Botrytis. In contrast to biotrophic pathogens, resistance to Botrytis may require multiple loci for full resistance. Botrytis may also trigger defense responses distinct from other pathogens. Recent efforts have identified loci in Arabidopsis required for resistance to Botrytis. Among these, the BOS1 gene encoding an R2R3MYB transcription factor protein is required for restricting pathogen growth in inoculated plants. The current knowledge on the genetic control of host resistance to plant pathogens has emerged from studies that involve interactions of plants with biotrophic pathogens.

b. *Impact:* Despite the significance of plant diseases caused by necrotrophic fungi resulting in millions of dollars in crop losses annually there have been limited studies on host responses to these group of pathogens. Disease control relies on fungicides that may stay as residues on produce presenting danger to human health, particularly from freshly consumed fruits and vegetables. No genetic resistance has been identified against many necrotrophic pathogens which also develop resistance to fungicides limiting their use. Currently, data on the genetic and molecular factors that control host responses to necrotrophic pathogens are limited.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

Key Theme: Plant Genomics (5)

a. *Description:* An Arabidopsis mutant, hos10-1 (for high expression of osmotically responsive genes), in which the expression of RD29A and other stress-responsive genes is activated to higher levels or more rapidly activated than in wild-type by low temperature, exogenous abscisic acid, or salt stress has been identified and characterized. The hos10-1 plants are extremely sensitive to freezing temperatures, completely unable to acclimate to the cold, and are hypersensitive to salt stress. Induction of NCED3 (the gene that encodes the rate-limiting enzyme in abscisic acid biosynthesis) by polyethylene glycol-mediated dehydration and abscisic acid accumulation are reduced by this mutation. Detached shoots from the mutant plants display an increased transpiration rate compared with wild-type plants. The hos10-1 plants exhibit several developmental alterations, such as reduced size, early flowering, and reduced fertility. The HOS10 gene encodes a putative R2R3-type MYB transcription factor that is localized to the nucleus. Together, these results indicate that HOS10 is an important coordinating factor for responses to abiotic stress and for growth and development.

b. *Impact:* This project provides basic information regarding the molecular genetic bases of plant tolerance to osmotic-based stresses including salinity, drought and freezing. Some genetic determinants controlling tolerance to these stresses have already been discovered and their usefulness in agricultural production should be determined in the next few years.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

Key Theme: Plant Genomics (6)

a. *Description:* Phosphate is one of the least available nutrients in the soil. The deficiency of phosphate results in poor plant growth and reduced yield. To overcome this problem, farmers around the world are applying large amounts of phosphate fertilizers to raise crops. Under natural conditions, plants tend to adapt to phosphate deficiency by altering their metabolism, physiology and morphology. Most of these

changes involve changes in gene expression. These changes enable the plants to obtain and utilize phosphate more efficiently. This research is focused on understanding the molecular mechanisms underlying plant adaptations to phosphate deficiency. In this context, several phosphate starvation induced genes including high affinity phosphate transporters, phosphatases, transcription factors and other novel genes have been isolated and analyzed. High affinity phosphate transporters involved in nutrient acquisition are represented by a gene family in plants. Analysis of the entire genome of Arabidopsis revealed concurrent changes in expression of hundreds of genes during phosphate deficiency. In addition, the interaction between sugar and phosphate in regulating gene expression is being analyzed using the model plant Arabidopsis. A combination of mutation and genetic approaches are being used to dissect the signal transduction pathway(s) initiated during phosphate deficiency.

b. *Impact:* Phosphate deficiency is global in nature and severely affects crop production. The goal of this research is to analyze important molecular and genetic components of phosphate starvation induced responses in plants. Many of the molecular determinants identified in the microarray analysis could be used for improving phosphate efficiency of cultivated plants. Studies on transcriptional regulation and mutation based screening are likely to lead to a better understanding of plant adaptation to nutrient deficiency. In addition, an in depth analysis of phosphate starvation mediated molecular responses will facilitate development strategies to generate phosphorus efficient plants in the future.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

Key Theme: Animal Genomics (1)

a. *Description:* An experimental model organism, the Japanese medakafish, was used to test the possibility of transgene introgression into natural populations. In medaka, growth-hormone transgenic males grow significantly larger than wild-type males. Females prefer to mate with larger males, and molecular assessments of parentage indicate that larger males obtain more fertilizations than smaller males. Despite this mating advantage, transgenic males have a viability disadvantage. Under certain circumstances, transgene introgression into a natural gene pool can have devastating consequences, including extinction of the natural population.

b. *Impact:* This research is having a theoretical impact (population genetics theory) as well as a practical impact (conservation biology).

c. *Source of Federal Funds:* Hatch and National Science Foundation

d. *Scope of Impact:* United States

Key Theme: Apiculture (1)

a. *Description:* Humans and bees may share some of the same metabolic and neurological syndromes associated with alcohol use. Assays for honey bee defensive behavior that include the learned response that bee colonies have to repeated disturbances have been developed. In addition, a QTL responsible for the high metabolic rate in Africanized bees has been mapped. The high metabolic rate may influence defensive behavior. The QTL that influence guarding behavior has been mapped. These QTL indicate the location of genes that influence this behavior that causes colonies to have a higher tendency to sting. Highly defensive Africanized bees efficiently recruit gentle European bees to sting when they are living together in the same colony. This is important because beekeepers always have a mixture of genotypes in their hives because queens mate "on the wing" with about a dozen males. Hybrid colonies with African

paternity sting just as much as the African parental type, but hybrid colonies with European paternity are much less aggressive. This finding is very important because it means that if beekeepers replace queens in an Africanized area, their colonies will become highly defensive again as soon as a new queen is reared, and flies out and mates with African drones. This paternal effect of stinging behavior also indicates an epigenetic phenomenon is affecting behavior.

b. *Impact:* The discovery of paternal effects on stinging behavior will impact beekeeping management decisions. It is not acceptable to allow queens to mate with drones from defensive colonies because the mating will result in a colony that is just as defensive as the drone colonies. More significantly, the discovery of a paternal effect shows that genes can have an unpredictable effect on this behavior because the expression of genes influencing defensive behavior depends on whether the gene was inherited from the mother or the father. This "imprinting" phenomenon has been reported in other animals, but this is the first report, as far as we know, of a paternal effect on natural variation in behavior.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

1C. Plant Stress Management

Key Theme: Plant Production Efficiency (1)

a. *Description:* The effects of P and K fertilization on alfalfa taproot reserve accumulation, especially taproot protein accumulation and composition, and expression of vegetative storage protein genes is critical. Treatments included a factorial combination of four P treatments (0, 25, 50, and 75 kg ha-1 yr-1) and five K treatments (0, 100, 200, 300, and 400 kg ha-1 yr-1). Taproots were sampled in May and December of each year. In December, alfalfa taproots supplied P had higher starch and lower sugar concentrations than taproots of plants not fertilized with P, whereas in May P fertilization reduced taproot starch concentrations and increased taproot sugar levels. Fertilization with K increased taproot sugar, but decreased taproot protein levels. Taproots of P-fertilized alfalfa had increased protein and amino acid concentrations when compared to plants not fertilized with P. Fertilization with P decreased vegetative storage protein transcript abundance, whereas application of K increased vegetative storage protein transcript levels. The role of stubble C and N reserves and residual leaf area on the contribution of taproot C and N reserves to alfalfa shoot regrowth after cutting was analyzed. The effects of two cutting heights (6 or 15 cm), two residual leaf areas (0 or 100%), and two initial C and N reserve levels (High N or Low N) were followed on forage production, N distribution, and C and N reserve dynamics within stubble and taproot. Herbage production was mainly affected by the initial taproot C and N reserve levels. However, stubble organic reserve levels (and to a lesser extent the residual leaf area) also influenced early shoot regrowth. Increased cutting height enhanced the contribution of stubble C and N reserves to regrowing shoots, but this effect was present only for one defoliation-regrowth cycle.

b. *Impact:* Principles of forage legume management are based almost exclusively on knowledge of taproot carbohydrate reserves. Taproot nitrogen reserves are as important, and possibly more important than cabohydrate reserves in controlling herbage regrowth after harvest, plant persistence, and ultimately yield. Producers can control certain factors in alfalfa production including fertilization with P and K, mowing height, and timing and frequency of cutting. These studies reveal that taproot N reserves are influenced by these management inputs, and explain much of the success (and failure) of alfalfa to grow and persist. Alfalfa management strategies that increase cutting height (and residual leaf area) during the penultimate harvest in autumn should be considered in cold regions with significant winter stress in order to improve alfalfa winter survival and persistence, as well as spring herbage regrowth.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Midwest

Key Theme: Plant Production Efficiency (2)

a. *Description:* In fungicide trials on wheat at two locations, Stagonospora leaf blotch developed late in the season, and by mid June there were substantial differences in the degree of necrosis on the flag leaf between treated and untreated plots. No Fusarium head blight symptoms developed at either location, owing to dry weather. There were likewise no visibly Fusarium-damaged kernels in the grain from any plot. Although there were significant differences in DON content among treatments at both locations, all DON levels were far below the level of concern. Airborne inoculum of Gibberella zeae and head blight development were monitored in wheat plots with or without corn residue on the soil surface. Hourly temperatures during the week before wheat flowered fell mostly in a favorable range for inoculum production (between 9 and 30 C), but there were a few hours of relative humidity greater than 90 percent. On only 2 days during this period were there more than 8 hours when temperature was in a favorable range while relative humidity was greater than 90 percent. Very little rain fell during this period. Airborne inoculum in each residue treatment was monitored with a Burkard volumetric spore sampler. On most days, no propagules of G. zeae were captured. The highest count recorded was 0.22 cfu per cubic meter per day, and this was in early June, well after flowering. Inoculum levels were also assessed by washing spores quantitatively from heads of cultivar Patterson collected each day from the two residue treatments. An average of 1.1 and 1.3 propagules were recovered per head each day from the no residue and residue treatments, respectively. On more than half of the days, no propagules were recovered. The highest numbers recovered were 5.5 for the no residue treatment and 13.3 for the residue treatment. No head blight developed on any of the wheat cultivars or on barley. Dry weather before and during wheat flowering greatly reduced the production of inoculum by Gibberella zeae, which prevented development of head blight in this experiment. No head blight developed in wheat cultivar trials planted at 5 locations throughout Indiana, where weather was similarly dry. There were no scabby kernels in the grain harvested from these trials.

b. *Impact:* This research contributes data for the development of a weather-based risk model for Fusarium head blight of wheat. This model is deployed on the Web, for all states where head blight is a threat. The fungicide trials generate data that can be used to support an application to the U.S. Environmental Protection Agency for a Section 18 registration of Folicur fungicide for use against head blight. This research also generates data to support registration of experimental fungicides.

c. *Source of Federal Funds:* Hatch and USDA-Agricultural Research Service

d. *Scope of Impact:* United States

Key Theme: Plant Production Efficiency (2)

a. *Description:* Insect populations were monitored in Indiana, focusing particularly on populations of soybean aphid, soybean thrips and the predator, Orius insidiosus. In 2004, soybean aphid first appeared in the field on 15 June, but did not begin to increase until 13 July. The dynamics of O. insidiosus were not dependent on soybean aphid densities, but likely to be driven to a large extent by thrips dynamics. The numerical response by the predator to thrips is reproductive rather than aggregative at the field level. To further document aphid dynamics, weekly surveys were conducted in 38 fields located in 28 counties in Indiana. In cooperator-surveyed fields where soybean aphid populations were present, peak soybean aphid severity ranged from 0.1 to 2.5. The mean number of aphids per plant exceeded 100 in only 4 fields, all located in the southeast (Dearborn and Jefferson) or north-central (Grant and Tippecanoe) parts

of the state. One of those fields (Tippecanoe), however, was the only field in our survey that was double-cropped after wheat. An adjacent field planted at the standard time for soybean failed to reach aphid densities of greater than 100 per plant. Soybean aphid arrived into each field at widely ranging dates, as early as 2 June in Miami and as late as 1 September in Bartholomew. Only in the northern half of the state, however, were aphids found as early as June. In the 15 fields in north-central Indiana that our group surveyed weekly, O. insidiosus arrived earlier than soybean aphid in all but two fields. The earlier the predator arrived relative to soybean aphid arrival, the lower was the peak soybean aphid density per plant in that field during the season.

b. *Impact:* Understanding the fundamental mechanisms underlying soybean aphid dynamics will provide pest managers better control options. The contribution of predators to soybean aphid dynamics is critical to its pest status.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Midwest

Key Theme: Plant Production Efficiency (3)

a. *Description:* A sweet corn insecticide trial was conducted that included several pyrethroid insecticides because of reports in 2003 and 2004 of failure of pyrethroids to provide acceptable levels of control of corn earworm in several areas of the Midwest. Pyrethroids in the study included lambda cyhalothrin (Warrior), bifenthrin (Capture), zeta-cypermethrin (Mustang Max), esfenvalerate (Asana), and cyfluthrin (Baythroid). Lowest labeled rates of each product was used to assess the possibility of resistance developing. Populations of corn earworms were extremely high, with 98% of the ears in the untreated plots infested with an average of 1.4 corn earworm larvae per ear. Percent control when compared to the untreated plots ranged from 5.7% for cyfluthrin to 26.2% for bifenthrin. The lowest labeled rate of spinosad (SpinTor), a non pyrethroid, provided somewhat better control at 37.6%. Larvae were collected from these plots and laboratory colonies established for LD50 testing.

b. *Impact:* Sweet corn is an important crop grown in Indiana. The corn earworm in sweet corn is one of the primary pest problems facing growers. Growers rely on one or more pyrethroid insecticides for control of this pest. In recent years, there have been a number of reports of control failures, suggesting that resistance may be involved. Studies conducted in 2004, and especially in 2005, provided evidence that pyrethroid resistance may be indeed be present.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Midwest

Key Theme: Plant Production Efficiency (4)

a. *Description:* A high-bay room was used to prove the feasibility of growing Bt corn under HID lamps as a sole source of light. Different combinations of high-pressure sodium and metal halide lamps were compared for their effects on vegetative growth. Three dwarf corn lines were grown under four different light spectra. A growth chamber of 11-foot height clearance was installed. In an optimizing environment, Bt corn grew over 11 feet. A pilot semi-controlled plant-growth facility was designed and constructed within the Marengo mine complex in southern Indiana to determine the feasibility of growing Bt corn and other crops underground. HID lamps were used both as the light source as well as the heat source in the facility. The naturally cool mine temperature was leveraged to prevent overheating in the growth facility.

Environments were identified that lead to normal corn-crop development in an underground growth facility, and adequate seed yield occurs using HID lamps as sole light sources.

b. *Impact:* The pharma-crop experiments not only prove the feasibility of growing corn with HID lights in a controlled environment, but also defined appropriate light intensity, planting media, pot size, and fertigation regimes for Bt corn growth. These studies provide guidelines to select HPS/MH lamp combinations for best crop performance, as well as a framework for designing the underground controlled environment facilities. The mine facilities not only validated the feasibility of growing corn (and other crops) in a controlled underground environment, but also provided the Controlled Pharming Ventures company with 700 square feet of controlled environment space that can be used either for research or for commercial production.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Midwest

Key Theme: Ornamental/Green Agriculture (1)

a. *Description:* This project is investigating factors that influence fungicide performance on golf course fairways. The study evolved from observations that disease was not adequately managed on numerous golf courses where isolates of Sclerotinia homoeocarpa were sensitive to commonly used fungicides. Factors under investigation include the residual efficacy of commonly used fungicides, the interaction of fungicides with plant growth regulators, and the spray volume used to deliver fungicide to the turf. A bioassay was developed to address the residual activity of contact and penetrant fungicides used for control of dollar spot on creeping bentgrass fairways. Results indicate that efficacy is drastically reduced ten days after application for all fungicides tested. Efficacy half lives for contact fungicides ranged from 6 to 9 days. Efficacy half lives for penetrant fungicides ranged from 10 to 15 days. The results support observations and experiences of turf managers regarding severe disease outbreaks before the end of recommended application intervals. They also suggest that timing of fungicide applications with respect to the onset of disease-favorable weather has a significant influence on fungicide performance. The interaction between fungicides and plant growth regulators resulted in different trends for contact and penetrant products. Preliminary results show that expected turf recovery with a penetrant fungicide was significantly delayed if plant growth regulators also were applied. Spray volume research is in its initial stages, but initial results indicate that levels of disease control were significantly reduced where the volume of water used to deliver fungicides was less than 1.5 gal per 1000 square feet.

b. *Impact:* An understanding of factors that influence fungicide performance will help golf course superintendents make informed decisions regarding the use of fungicides for disease control. The objective is to establish economically and environmentally sound approaches to disease management. Previous research demonstrated that on some golf courses, unacceptable levels of control could be attributed to an inherent insensitivity (resistance) in the predominant pathogen population. However, there are many cases where outbreaks are severe, despite the predominance of fungicide-sensitive strains. We are interested in understanding a variety of other factors that influence fungicide performance including spray volume, interaction with growth regulators, nitrogen nutrition, and cultivar susceptibility. Knowledge of how these factors influence fungicide performance will improve disease management skills and result in less turf damage, quite likely with less fungicide.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Midwest

Key Theme: Organic Agriculture (1)

a. *Description:* Microsphaeropsis amaranthi isolated from Amaranthus sp. is a virulent pathogen of common waterhemp (A. rudis Sauer), one of the key weeds of the Midwest. This research is investigating the potential for M. amaranthi to be integrated into production systems for the control of common waterhemp. The optimum and limiting conditions for activity of M. amaranthi have been determined in a series of lab and field experiments. The growth and sporulation of the fungus is limited at temperatures below 15C and above 30C. The fungus required a period of leaf wetness of more than 12 hours for optimum activity, and infection was limited with a dew period of less than 10 hours at a temperature below 18C or above 24C. In the field, spray applications of M. amaranthi caused damaging infections on days characterized by temperatures and dew periods within the range above, and infection failed when conditions were not within this range. M. amaranthi has a strong positive interaction with the herbicide glyphosate. When plants were sprayed sequentially with sub-lethal rates of glyphosate and M. amaranthi, plants were killed. This may have particular value for common waterhemp control in glyphosate resistant soybean. A number of adjuvants commonly used with herbicides inhibited germination in M. amaranthi which may preclude the mixing of conidia into the spray tank for combined applications in an integrated weed management system. The fungus does not sporulate in submerged culture, and requires light for sporulation. However, the fungus grows and sporulates freely on a range of crude agricultural products. Spray application is most efficient when conidia of M. amaranthi are applied using spray tips that generate fine, swirling droplets. When sprayed with a hollow cone nozzle tip (such as is typically used for fungicide applications) at high pressure, rather than a flat fan nozzle tip (such as is typically used for herbicide applications) the fungus caused elevated levels of disease on the stem base of common waterhemp plants. These stem infections resulted in higher levels of plant mortality.

b. *Impact:* There is the potential to integrate a bioherbicidal fungus into Midwestern production systems for the control of common waterhemp. Limiting factors have been determined: inhibition by adjuvants and poor performance under dry conditions. Progress has been made on improved production of conidia, optimized applications system and evaluation of herbicide synergies.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Midwest

Key Theme: Plant Germplasm (1)

a. *Description:* Soybean germplasm has been developed that confers complete and broad-based resistance to soybean cyst nematode. Good soybean varieties with this germplasm (known commercially as CystX) continue to be grown in soybean fields in several states, and more varieties are in the process of development by commercial breeders. In collaboration with the Indiana Crop Improvement Association and partially funded by the Indiana Soybean Board, the germplasm is licensed and marketed by ACCESS Plant Technology. Commercial development has been slowed by the complex genetics of the technology. A single nucleotide polymorphism linked to the major quantitative trait locus (QTL) of resistance in our germplasm has been discovered and developed. Using a soybean cyst nematode bioassay with susceptible and resistant genotypes and also with plant introductions with different levels of soybean cyst nematode resistance this single nucleotide polymorphism technique has been verified. The test can be performed using any soybean tissues (e.g., a leaf) and will save plant breeders the time, labor and funds required by traditional assays. It has also been documented for the first time that soybean cyst nematode is capable of reproducing on purple deadnettle in the field in the absence of susceptible soybean varieties.

b. *Impact:* Because soybean cyst nematode is the most destructive pest of soybeans, commercial plant breeders are eager to speed development of high yielding soybean varieties that incorporate the resistant

germplasm, CystX. Discovery of the single nucleotide polymorphism molecular marker will speed the breeding process and permit more rapid deployment of high yielding CystX varieties in all maturity groups.

c. Source of Federal Funds: Hatch

d. Scope of Impact: Midwest

Key Theme: Plant Genomics (1)

a. Description: The cowpea bruchid, Callosobruchus maculatus (F.), a pest of stored cowpea grain throughout the world, causes tens of millions of dollars worth of damage annually. One method of managing this pest involves planting cowpea cultivars whose seeds are resistant to bruchids. Despite extensive research, the mechanism by which TVu 2027, the original bruchid-resistant cowpea line and the source of resistance genes now present in many cowpea cultivars, is not known. Using micro-Computerized Axial Tomography scan imaging the feeding patterns of bruchids living and growing within resistant and susceptible cowpea seeds have been observed. Virulent as well as avirulent bruchid strains have different feeding patterns in TVu 2027 seeds compared to susceptible seeds. They penetrate less deeply into the resistant seeds than they do in susceptible ones. Based on micro-CAT scanning, the resistance factor in TVu 2027 is most concentrated in an interior zone in each cotyledon adjacent to the airspace separating the two seed halves. Artificial seeds made from the most interior zone of the cowpea seed were much more toxic to bruchids than were artificial seeds made from the peripheral layers of the seed. With limited technologies available for managing cowpea bruchids, transgenic cowpeas with bruchid resistance genes engineered into them could become a management tool in the future. There is a question as to which gene or genes might be useful for this purpose and whether two or more genes might be combined to create a more resistant cowpea. Two different sets of potential transgenic insecticidal proteins were investigated using an artificial seed system. When a coleopteran-active Bt strain (CIP-PH-Bt-J; 1000 ppm) and recombinant egg white avidin (60 ppm) were incorporated separately into artificial seeds, 98.2% and 99% larval seed mortality, respectively, was observed. Combining the Bt and avidin in the same seed provided redundant killing; no insects survived. When avidin and wheat alpha-amylase inhibitor (AAI) (10,000 ppm) were incorporated separately into artificial seeds made with garden pea flour, there was 99.8% and 98% mortality, respectively. When the two proteins were combined, they did not increase mortality, although there was an increase in developmental time. These results indicate that the joint action of potential insecticidal compounds cannot be predicted based on results with the individual compounds.

b. Impact: Genetic engineering of crop plants to impart resistance to insects is now a well-established and widely adopted technology for insect management. While genes from the Bacillus thuringiensis have been the primary genes used to confer insect resistance, additional genes and combinations of genes need to be explored for potential future applications. The current work shows that certain combinations of genes may be useful for the control of the cowpea bruchid feeding on cowpea grain.

c. Source of Federal Funds: Hatch

d. Scope of Impact: Midwest

Key Theme: Plant Genomics (2)

a. Description: The plant hormone abscisic acid plays a pervasive role in the adaptive responses of crop plants to osmotic stress. Its role in mediating rapid physiological responses such as stomatal closure, root hydraulic conductivity, dormancy initiation and control of cellular ion and osmotic homeostasis have been

studied for more than thirty years, and these mechanisms are relatively well defined. Much less is known, however, regarding the early events of gene expression and the initiation of signaling cascades that govern these physiological responses. Therefore, a screening protocol was devised using Arabidopsis thaliana to evaluate sensitivity to salt and to identify stress-signaling mutants. The screen, which evaluated reduction in root growth on 150 mM of salt led to the identification of an untagged mutant designated nsr (a salt sensitive root) with severe reduction in root growth. The mutation has been shown to be a single recessive nuclear gene trait. It confers sensitivity to osmotic, but not ionic stress. Further, this mutant displayed altered germination and stomatal regulation responses, suggesting a defect in abscisic acid biosynthesis. Novel among previously-discovered abscisic acid biosynthesis mutants, however, water loss from either excised shoots or whole plants was not inhibited by exogenous abscisic acid. This result suggests dysfunction in the normal abscisic acid-mediated signal cascade leading to stomatal closure.

b. *Impact:* Abscisic acid participates in the rapid physiological adaptation of plants to their environment by inducing changes in guard cell signal cascades and ion channels that bring about rapid stomatal closure. Although genes for more than 17 abscisic acid signaling intermediates have been reported in the literature, our understanding of these signaling pathways remains fragmentary. The present research has identified a novel locus that not only affects abscisic acid biosynthesis, but also appears to regulate abscisic acid signal cascades. This dual-function gene may exert a critical regulatory role in the control of stomatal aperture during periods of drought.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Midwest

Key Theme: Biotechnology (1)

a. *Description:* Two of the most important scientific events of the twentieth century were the green revolution and the development of antibiotics. The green revolution, with the large-scale use of insecticides and herbicides, has increased the quantity and quality of food for an ever-growing human population. Antibiotics have dramatically reduced the mortality rates of the human population caused by bacterial diseases. However, the Achilles heel of both these scientific advances has been the evolution of pesticide and antibiotic resistance. Once widespread resistance develops, the chemical (or chemical-class) is typically abandoned. The subsequent focus, in the academic and industrial research community, is to identify and deploy novel pesticides and antibiotics with different modes of action. This research program is dealing with insect genomics with a long-term intent of discovering novel target-sites for the development of alternative methods of insect control. The genes in Drosophila that confer metabolic resistance to imidacloprid and DDT also confer negative cross-resistance to other classes of compounds. Negative cross-resistance is one alternative to the use-and-discard approach to control organisms containing the resistant allele (through use of toxins that preferentially kill pesticide resistant insects). Negative cross-resistance toxins preferentially kill pesticide-resistant insects. Our group has investigated the molecular basis of negative cross-resistance in pesticide-resistant Drosophila and identified negative cross-resistance factors using a screening strategy developed by Pittendrigh and Gaffney (2001). Metabolic pesticide-resistant Drosophila lines are known to exhibit negative cross-resistance to other classes of compounds. If there is a common underlying gene or set of genes causing resistance across all fly lines this would lay the foundation for discovery of a useful negative cross-resistance compound for metabolic resistance.

b. *Impact:* The long term goal is to develop sustainable strategies for minimizing pesticide resistance in insect populations. Research over the past year represents significant steps towards this goal.

c. *Source of Federal Funds:* Hatch and National Institutes of Health

d. *Scope of Impact:* Midwest

Key Theme: Biotechnology (2)

a. *Description:* Concentrations of glutathione, cysteine, and O-acetyl-L-serine, in shoot tissue, are strongly correlated with the ability to hyperaccumulate nickel in various Thlaspi hyperaccumulators collected from serpentine soils and non-accumulator relatives. Further analysis of the Austrian nickel hyperaccumulator T. goesingense, revealed that the high concentrations of O-acetyl-L-serine , cysteine and reduced glutathione observed in this hyperaccumulator coincide with constitutively high activity of both serine acetyltransferase and glutathione reductase . These changes in cysteine and reduced glutathione metabolism also coincide with the ability of T. goesingense to both hyperaccumulate nickel and resist its damaging oxidative effects. Over-production of T. goesingense serine acetyltransferase in the non-accumulator Brassicaceae family member A. thaliana was found to cause accumulation of O-acetyl-L-serine , cysteine and glutathione, mimicking the biochemical changes observed in the nickel hyperaccumulators.

b. *Impact:* A better understanding of the mechanisms underlying metal hyperaccumulation in plants could lay the foundations for the development of plants with reduced accumulation of potentially toxic trace metals in their edible parts. Also, such information could be used to develop plants for removal of pollutant metals from the environment.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Midwest

Key Theme: New Uses for Agricultural Products (1)

a. *Description:* The structural changes taking place in the pericarp of microwaveable popcorn were investigated. Both x-ray diffraction and calorimetric studies showed that the pericarp is crystalline due to its cellulose component and this attribute increases during microwaving so as to hold the moisture inside until the kernel bursts. Thus, the higher the crystallinity, the better the kernel pops.

b. *Impact:* The cellulose component of pericarp in microwaveable popcorn holds the key to popping performance.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Midwest

1D. Animal Disease, Health, and Well-Being

Key Theme: Animal Genomics (1)

a. *Description:* Somatic stem cells have been isolated from porcine skin and the developing olfactory bulb using established protocols. The cells were characterized by the expression of the pluripotent marker Oct-4.These cells, together with differentiated fetal fibroblast cells, are being used for nuclear transfer and to investigate whether there is any difference between the behaviors of the various cell types during reprogramming. Using immunocytochemistry it was found that fibroblast cells possess A type lamins in

their nuclear envelope consistent with previous findings that differentiated cells express lamin A/C. Progenitor cells on the other hand don't have lamin A/C in their nuclear envelope. After transferring the cells into enucleated oocytes, the nuclear envelopes break down during chromatin remodeling and lamin A/C staining disappears in the case of both differentiated and non-differentiated cells. It becomes detectable again after the formation of pronuclei when a new nuclear envelope is assembled. The assembly did not result from de novo lamin A/C gene transcription, but from solubilized lamins already in the oocyte cytoplasm. The results imply that lamin A/C is present in early pig embryos and its presence after nuclear transfer is not an indicator of erroneous reprogramming unlike reported in cattle and mouse. Most somatic cells have a highly methylated genome, a characteristic of differentiated cells. In contrast, early embryonic cells are typically hypomethylated due to genome-wide DNA demethylation that occurs after fertilization. However, in cloned bovine embryos produced using somatic cells, methylation levels of several repeat and unique DNA sequences were found to be much higher than in normal embryos. In the olfactory bulb progenitor cells the relative degree of methylation was significantly higher than that in the fetal fibroblast cells. When used as nuclear donors during nuclear transfer, nuclei of olfactory bulb progenitor cells supported early embryonic development after nuclear transfer effectively; the low level of methylation in these cells may have contributed to the high developmental potential of the reconstructed embryos.

b. *Impact:* Nuclear transfer is rapidly becoming the predominant technique for the production of transgenic livestock. Improving nuclear transfer technology would make the production of transgenic animals more efficient that offer great benefits not only in agriculture, but in human therapeutics as well. Finding cell types that could be reprogrammed completely during nuclear transfer would significantly improve development of the resulting embryos. Somatic stem cells seem to be good candidates since they may require less reprogramming due to their unique epigenetic makeup.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

Key Theme: Animal Production Efficiency (1)

a. *Description:* The effect of an E. coli derived phytase on phytate-phosphorus utilization and growth performance for young pigs was evaluated. The first experiment involved time course, pH-dependence, and phytase-activity studies to investigate the in vitro release of P from corn, soybean meal, and an inorganic P unsupplemented corn soybean meal negative control diet. Experiment 2 was designed to determine the efficacy of the E. coli derived compared with a fungal phytase added to diets at 0, 250, 500, 750, 1,000, or 1,250 FTU/ kg . In a positive control diet, eight individually-penned 10-kg pigs/diet (12 diets, 96 pigs) were used in a 28-d growth study. The third experiment was a 10 day nutrient balance study involving six 13-kg pigs/diet (4 diets, 24 pigs) in individual metabolism crates. In experiment 4, eight pens (4 pigs per pen) of 19-kg pigs/treatment were used in a 42 day growth performance study to examine the effect of adding the E. coli derived phytase to corn-soybean diets at 0, 500 or 1,000 FTU/kg and a positive control (4 diets, 128 pigs). In experiment 5, six 19-kg pigs/treatment were used in a 10 day nutrient balance study to investigate the effects of the E. coli derived phytase added to diets at 0, 250, 500, 750, or 1,000 FTU/ kg and a positive control diet (6 diets, 36 pigs). The in vitro study showed that the E. coli derived phytase has optimum activity and pH range of 2 to 4.5; inorganic phosphate release was highest for soybean meal, lowest for corn, and intermediate for the negative control diet. Dietary supplementation with graded amounts of E. coli derived phytase resulted in linear increases in weight gain, feed efficiency, and plasma Ca and P concentrations of 10-kg pigs. Phytase also improved P digestibility and retention in the 13-kg pigs. Dietary supplementation with E. coli derived phytase resulted in linear increases in weight gain and feed efficiency of 19-kg pigs. Supplementation of the diets of 19-kg

pigs with the E. coli derived phytase also improved Ca and P digestibility and retention. The new E. coli derived phytase was efficacious in hydrolyzing phytate-P, both in vitro and in vivo in young pigs.

b. *Impact:* Escherichia coli-derived phytase is efficacious in phosphorus hydrolysis when added to pig diets. The research demonstrated that the new E. coli-derived phytase was efficacious in hydrolyzing phytate-P, both in vitro and in vivo in young pigs and may help reduce excretion of phosphorus in pig manure. Efficient utilization of plant sources of phosphorus by pigs is important in reducing manure phosphorus excretion.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Multi-State

Key Theme: Managing Change in Agriculture (1)

a. *Description:* This project explores conventional and novel roles of behavior in both measuring and resolving wellbeing issues in farm and laboratory animals while preserving profitability and scientific data quality. The effects of cage design on laying hen feeding behavior, physiology, production, and wellbeing were investigated. Subtle aspects of cage design, particularly the amount of feeder space available per hen, cage height, and the relative placement of resources such as feeders and drinkers in the cage, probably have marked effects on feeding behavior. For instance, in cage configurations where high ranking birds can block access to the feeder, low ranking birds may progressively lose condition, drop out of production and become at risk for mortality.

b. *Impact:* The wellbeing of farm animals is an issue of increasing concern to the general public. Our work with poultry is designed to identify ways in which improving animal wellbeing will also improve the profitability of egg production, benefiting both hens and producers.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Multi-State

Key Theme: Animal Genomics (1)

a. *Description*: Bone fractures at the end of lay are a significant problem in egg-laying strains of hens. The objective of the study was to identify quantitative trait loci associated with bone mineralization and strength in a chicken resource population. Layer (White Leghorn hens) and broiler (Cobb-Cobb roosters) lines were crossed to generate an F2 population of 508 hens over seven hatches, and 26 traits related to bone integrity, including bone mineral density and content, were measured. Genotypes of 120 microsatellite markers on 28 autosomal groups were determined, and interval mapping was conducted to identify quantitative trait loci regions. Twenty-three tests representing three chromosomal regions (chromosomes 4, 10 and 27) contained significant quantitative trait loci that surpassed the 5% genome-wise threshold, and 47 tests representing 15 chromosomes identified suggestive quantitative trait loci quantitative trait loci that surpassed the 5% chromosome-wise threshold. Although no significant quantitative trait loci influencing bone mineral density and bone mineral content were detected after adjusting for variation in body weight and egg production, multiple suggestive quantitative trait loci were found. These results support previous experiments demonstrating an important genetic regulation of bone strength in chickens, but suggest the regulation may be due to the effects of multiple genes that each account for relatively small amounts of variation in bone strength.

b. *Impact:* This research has identified genomic regions that contribute to variation in bone traits among chickens. Further investigation of these genomic regions will contribute to the implementation of selection strategies aimed at improving bone integrity in chickens without deleteriously affecting egg production and shell quality.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Multi-State

Key Theme: Animal Genomics (2)

a. *Description:* It is well documented that feeding beta-agonists, in particular, ractopamine induces nutrient partitioning towards lean muscle growth and changes in muscle protein-specific gene expression are associated with increased protein accretion. Differential up-regulation of muscle fiber type specific genes has not been demonstrated, however. To that end, crossbred pigs were fed 20 ppm ractopamine over a four week period to determine whether beta-agonist stimulation of muscle resulted in a differential expression of muscle fiber type-specific genes. Using semi-quantitative PCR methods, type I myosin heavy chain isoform gene did not change over the 4 week study. In contrast, type IIB myosin heavy chain gene expression increased by week one and remained elevated throughout the study. Type IIA myosin heavy chain gene expression was increased by week one and remained elevated through week two, but returned to control levels by week four. In contrast, type IIX(D) mRNA content in the longissimus muscle decreased over the four week period. Glycogen synthase expression decreased by week one, but returned to control levels by week two; by week four, however, expression decreased below initial levels. Citrate synthase expression decreased by week two and stayed lowered through the remainder of the study. As mentioned, beta-agonists induce skeletal muscle hypertrophy and antagonize atrophy. The molecular mechanisms controlling these phenomena are not, however, well-known. Using both in vitro and in vivo approaches, it has been shown that beta-agonists exert a distinct muscle fiber type-specific hypertrophy that is preferentially restricted to fast-twitch fibers.

b. *Impact:* Muscle growth and meat quality are inherently important to the animal industry. Muscle consists of a collection of multinucleated muscle fibers differing in their abilities to contract and metabolize energy sources. Mechanisms controlling muscle fiber specialization and differentiation is particularly fascinating because changes in the abundance of each fiber type in muscle of growing mammals is associated with the ultimate growth and meat quality attributes in pigs. Cellular signals responsible for conferring muscle fiber type-specific gene expression have been identified. This represents a significant breakthrough in our understanding of the molecular mechanisms controlling muscle fiber diversification. It is now possible for genetic and pharmaceutical companies to select pigs for a more desirable muscle fiber type composition and/or development strategies to clinically change this composition to improve growth efficiency, respectively.

c. *Source of Federal Funds:* Hatch and USDA-National Research Initiative

d. *Scope of Impact:* Multi-State

Key Theme: Animal Health (1)

a. *Description:* Of concern in the control of infectious bursal disease virus infection is the steady progression of viral evolution over recent decades and the emergence of both new antigenic variants and strains with enhanced virulence. Effective control of infectious bursal disease is contingent on the availability of rapid and efficient diagnostic procedures for identifying and differentiating infectious bursal disease virus strains within a flock. Currently, there is no single-step assay available that will

rapidly identify and differentiate infectious bursal disease virus strains. A real-time reverse transcription polymerase chain reaction assay was developed utilizing dual-labeled fluorescent probes binding to infectious bursal disease virus VP4 sequence that are specific to the classical, variant or very virulent subtypes of infectious bursal disease virus. The assay was highly sensitive. Viral genomic copy number could be accurately assayed over a broad range of 7 to 8 logs of viral genome. The variant-sequence specific probe was found to be highly specific in detecting isolates classified as variant A, D, E, G and GLS-5, and did not react with classical strains. A total of 130 field and experimental variant strain isolates were tested using this assay.

b. *Impact:* Rapid identification of infectious bursal disease virus strains is a primary concern to poultry industry to ensure administered vaccines will protect against current strains of infectious bursal disease virus circulating in the flock. The ability to concurrently quantify infectious bursal disease virus titer is also of assistance in identifying the progression of disease outbreaks within the flock. The developed real-time PCR is advantageous in the rapid and accurate diagnosis of infectious bursal disease virus flock status for the effective control of infectious bursal disease virus.

c. *Source of Federal Funds:* Animal Health

d. *Scope of Impact:* United States

Key Theme: Animal Health (2)

a. *Description:* Homeostatic migration of T cells to the small intestine involves the CCL25-CCR9 chemokine axis. However, it has been unclear which chemo-attractant system is involved in T cell migration to chronically inflamed lesions of the small intestine. SAMP1/Yit mice develop a spontaneous chronic transmural intestinal lesion specifically in the ileum. Using these mice, the gut chemokine network involved in T cell migration to the inflamed lesion versus a normal intestinal segment was investigated. The expression of homeostatic chemokines is largely unchanged in the inflamed lesion of SAMP1/Yit mice compared to control mice. However, an additional chemokine axis (CCL5-CCR5) was detected in the inflamed intestine of SAMP1/Yit mice, but not in control mice. A major cell source of CCL5 is activated CD8+ T cells in SAMP1/Yit mice. Activated T cells from SAMP1/Yit mice compared to control mice were hyper-responsive to CCL5 in chemotaxis. CCR5+ T cells preferentially migrate to the inflamed lesion, but not to the normal intestinal segment, which can be blocked by a CCR5 antagonist. These results suggest that a chronic-inflammation chemokine-network is additionally formed on top of the homeostatic chemokine network in the intestinal lesion of SAMP1/Yit mice for recruitment of immune cells that are, otherwise, excluded from the healthy small intestine.

b. *Impact:* Modulation of the chemokine-chemokine receptor network can be a useful tool to control intestinal inflammation. Abnormal expression of chemokines can indicate developing intestinal inflammation, and thus has diagnostic value.

c. *Source of Federal Funds:* Animal Health

d. *Scope of Impact:* United States

Key Theme: Animal Health (3)

a. *Description:* To investigate the effect of osmotic and secretory diarrhea on fecal electrolytes, an experiment was performed on 8 1-3 week-old Holstein bull calves. They were fed colostrum until 24 hours of age, then commercial calf replacer. Blood and feces were collected for control samples. All samples at all time points were frozen at -80 degrees within 3 hours of collection. Osmotic diarrhea was

induced by oral administration of sucrose (Domino Table Sugar). Five hundred grams of sucrose was added to the milk replacer at each feeding. The sucrose was given until the calf developed diarrhea as assessed by the presence of semi-liquid or liquid feces. This occurred within 12 hours of sucrose administration in all instances. Feces and serum were collected for analysis. Once samples were collected, the treatment was discontinued. All calves regained normal fecal consistency within 24 hours of cessation of sucrose. To induce a secretory diarrhea, phenolphthalein was given at a dosage of 25 mg/kg orally. It was given until diarrhea was detected, at which point feces and serum were collected and the treatment immediately stopped. Phenolphthalien-induced diarrhea was extremely transitory in nature, and even high doses of this substance had little effect. This was a cross-over design; each calf was given both sucrose and phenolphthalein in a randomized fashion. Although not originally designed as a cross-over, the calves developed diarrhea so quickly after treatment, and then had it resolve so rapidly after treatments were discontinued that it was felt that this was a valid experimental design. A minimum of a 48 hour wash out period was used between treatments. At the end of the final collection period, the calves were humanely euthanized.

b. *Impact:* This research will help reduce antibiotic use in calves and other food producing animals. Producers will have a means to rapidly differentiate diarrhea into either secretory or osmotic types. If an osmotic type is diagnosed (thought to be the most common type) the producer would know that no health benefit would be expected by antibiotic administration. Management factors could be reviewed if an osmotic diarrhea were found, and potential viral or parasitic etiologies could be investigated.

c. *Source of Federal Funds:* Animal Health

d. *Scope of Impact:* Indiana

Key Theme: Animal Health (4)

a. *Description:* Continuous intra-articular infusion of gentamicin into joints of horses has been shown to be safe and effective for obtaining high levels of gentamicin within equine joints. Practical techniques for placing catheters and pumps to administer continuous intra-articular infusion were developed and are fairly reliable. Levels of gentamicin over 50 times the minimum inhibitory concentration of most equine bacterial pathogens can be achieved. These high levels are needed to over-ride numerous factors which inhibit the effectiveness of gentamicin in an infected joint. These factors include a low pH, isolation of bacteria in fibrin clots, poor blood flow, areas of ischemia and necrosis in the synovial membrane and inactivation of gentamicin by high numbers of bacteria. The adverse effects of continuous intra-articular infusion on cartilage and synovial membrane were found to be minimal.

b. *Impact:* Horses with chronic or severe septic arthritis are now being treated routinely with local antimicrobial delivery. Constant intra-articular infusion of infected joints in horses is being utilized by numerous veterinarians on client owned animals. This method of antimicrobial delivery combined with systemic antimicrobial drug administration is very effective in elimination of the infective organisms. Clinical trials are ongoing and results suggest that this method will allow us to save some horses with very chronic joint infections or joint infections that have not responded to routine treatment.

c. *Source of Federal Funds:* Animal Health

d. *Scope of Impact:* Indiana

Key Theme: Bioterrorism (1)

a. *Description:* Biosecurity procedures to prevent the mechanical transmission of porcine pathogens were evaluated. First, aerobic bacterial culture was used to compare the effectiveness of the current USDA footwear disinfection protocol for airplane passengers contacting livestock to a novel protocol. The current protocol consists of brushing and dipping shoe soles in 1% Virkon S. The number of bacteria was not different between shoes treated with the current protocol and untreated shoes. No shoes met the standard for disinfection after the current disinfection protocol was completed. The novel protocol consisted of brushing shoe soles, wiping soles with a cotton towel soaked in 1% Virkon S, and drying soles with paper towels. The number of bacteria was less on treated shoes compared to control shoes. Eighteen of 20 shoes (90%) cleaned using the novel protocol met the standard for disinfection. Direct comparison of the current and novel protocols found that the number of bacteria cultured was less after implementing the novel protocol compared to implementing the current protocol. Again, no shoes treated using the current protocol met the standard for disinfection after the current protocol was completed. Under conditions of this study, current U.S. airport footwear disinfection protocols were inadequate to disinfect footwear when using aerobic bacteria as a marker for disinfection.

b. *Impact:* This novel shoe treatment procedure, if adopted at international airports, could have a wide impact on policy as governments and livestock producers revise their biosecurity and disease control procedures for both enzootic and exotic diseases. Current procedures of dipping shoe soles of airline passengers that have visited livestock facilities in foreign countries in 1% Virkon S were found to be ineffective; yet, the novel protocol of brushing shoe soles, wiping soles with a cotton towel soaked in 1% Virkon S, and drying soles with paper towels disinfected shoes at least 80% of the time. Continuation of applied biosecurity research is needed to maintain a healthy livestock system and a safe food supply for our nation.

c. *Source of Federal Funds:* Animal Health and USDA-Animal and Plant Health Inspection Service

d. *Scope of Impact:* United States

1E. Farm Business Management, Economics, and Marketing

Key Theme: Agricultural Profitability (1)

a. *Description:* Results of a random parameter logic model applied to choice data obtained from a nationwide survey indicates that more altruistic individuals are willing to pay more for pork products with public good attributes than less altruistic individuals and free riders. These results indicate that private purchases of goods with public-good attributes are not simply a result of individual perceptions of the ability to mitigate private risks such as food safety, but that individuals are making private choices to affect public outcomes. A generalized random utility model allows for a test of the linearity of the attribute-based utility function. Utility specification and individual heterogeneity intertwine such that a full investigation into either issue requires joint consideration. U.S. pork consumers are a heterogenous group that consists of three segments. The socially-conscious group, which represents sixteen percent of the sample, has the highest mean willingness to pay, but consumes the least pork. The second group, referred to as the price-conscious group, has the lowest willingness to pay. The associated class probability for this group is forty-one percent. The class probability for the third group, referred to as the mainstream group, is forty-three percent and their preferences are situated in between the concerned and the price-concerned group. The group has a positive significant willingness to pay for the certification programs. However, the mainstream group is not willing to pay as high price premium as the first group and opt for the conventional product if the price is too high.

b. *Impact:* Certification of pork production processes could increase market access and short-run profits.

c. Source of Federal Funds: Hatch

d. Scope of Impact: United States

Key Theme: Agricultural Competitiveness (1)

a. *Description:* This project explores alternative distribution channels for crop inputs. A survey determined what crop input dealers believe to be the major opportunities and threats facing their firms and how managers of these firms believe their firm's role in the distribution channel will evolve. More than 300 dealers responded to this survey. Key findings suggest that: 1) most dealers see their top challenges as internal issues such as insurance cost, access to quality employees, and energy costs; 2) the most important opportunities tend to be product and service focused, and are related to traditional sources of revenue, including seed sales, traditional agronomic services, and precision services; 3) dealers see their future sales and profit mix as including more seed, service, and information sales and profit, with less sales and profit coming from fertilizer and crop protection chemicals; and 4) most dealers see current high profile roles for both farmers and manufacturers becoming more important in the future, with an increased role in helping farmers comply with government regulations and providing on-going crop management services for farmers, and an increased role in tracking crop input use for regulatory purposes for manufacturers.

b. Impact: The survey of dealer opportunities and challenges has provided important insights into the strategic thinking of this level of the distribution channel. Dealers can use this information to better focus their strategic thinking and their suppliers can use this information as they develop programs in support of dealer businesses. This information has been presented to the industry through a series of trade press articles and presentations at industry meetings.

c. Source of Federal Funds: Hatch

d. Scope of Impact: United States

Key Theme: Agricultural Competitiveness (2)

a. Description: This international research project investigated the poverty impacts of a potential Doha Development Agenda that is being negotiated under the auspices of the World Trade Organization (WTO). Scenarios were analyzed using newly available tariff data and their implications for world markets are established using a global modeling framework. This forms the basis for thirteen country case studies of the national poverty impacts of these scenarios. The focus countries include: Bangladesh, Brazil (2 studies), Cameroon, China (2 studies), Indonesia, Mexico, Mozambique, Philippines, Russia, Vietnam and Zambia. The WTO liberalization targets have to be quite ambitious if the Doha Development Agenda round is to have a measurable impact on world markets, and hence poverty. Assuming a tiered formula for developed country agriculture, with marginal tariff cuts of 45, 70 and 75 percent, the near-term poverty impacts would be mixed; some countries experience small poverty rises and others more substantial poverty declines. On balance, poverty would be reduced and this reduction would be more pronounced in the longer run. Allowing minimal tariff cuts for just a small percentage of special and sensitive products reverses the results, with increases in global poverty. Deeper cuts in developing country tariffs would be more poverty friendly. Key determinants of the national poverty impacts include: the incomplete transmission of world prices to rural households, barriers to the mobility of workers between sectors of the economy, as well as the incidence of national tax instruments used to replace lost tariff revenue. In order to generate significant poverty reductions in the near term, complementary domestic reforms are required to enable households to take advantage of new market opportunities. Sustained long term poverty reductions depend on stimulating economic growth. In order to fully realize

their growth potential, trade reforms need to be far reaching, addressing barriers to services, trade, and investment in addition to merchandise tariffs.

b. *Impact:* The results of this study on the potential poverty reduction impacts of the Doha Development Agenda under negotiation at the World Trade Organization were presented twice in Geneva to trade negotiators during the spring of 2005. Allowing industrialized countries to exempt just two percent of their products from cuts under the so-called sensitive products proposal would largely eliminate the poverty reducing potential for such a WTO agreement. In addition, market access negotiations for developing countries is essential. Domestic subsidies for agriculture in the industrialized countries have an adverse impact on developing countries as a group. As a consequence of these presentations in Geneva, and the associated publications, a number of countries have reconsidered their negotiating positions.

c. *Source of Federal Funds:* Hatch and USDA-Economic Research Service

d. *Scope of Impact:* Global

Key Theme: Agricultural Competitiveness (3)

a. *Description:* One means of reducing farm program subsidies and increasing environmental attributes would be to pay farmers for carbon sequestration. Research in the Philippines quantified and valued carbon sequestration in smallholder agricultural and agroforestry systems. Marginal costs for carbon storage on fallow land were found to range between $3.30 and $3.90 per ton of carbon sequestered for both forestry and agroforestry systems. On low-input farms the carbon cost ranges from $25.00 to $25.50 per ton for conversion to forest and $24.20 to $25.30 per ton for conversion to agroforest. On high-input farms the carbon cost ranges from $61.10 to $62.50 per ton for conversion to forest and $46.70 to $48.00 per ton for conversion to agroforest.

b. *Impact:* This project has measured the direction and magnitude of policy linkages between economic changes and decisions of resource managers. The project has improved our understanding of farmer decision making regarding use of soils, water, and forests. In the Philippines, the research has identified factors associated with forest clearing and forest degradation.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Global

Key Theme: Precision Agriculture (1)

a. *Description:* This project: 1) evaluated of the economic feasibility of spatial and temporal management of crop inputs and practices, 2) developed statistical methods for using sensor data, and 3) examined the potential for knowledge intensive solutions to crop production problems that maintain or increase profits while at the same time improve the environment. Previous studies showed that corn nitrogen response varies widely from place to place within fields and season to season. This led to the hypothesis that variable rate nitrogen application would have risk management advantages. Site-specific yield response functions were estimated with data from Windom, Minnesota, and used in a partial budget framework. Net present value of variable rate N and P, variable rate N, and variable rate P strategies were compared to returns of a uniform management strategy. Contrary to expectations, risk aversion levels did not appear to have a major effect on N management in the baseline comparisons. In all cases, the uniform management strategy yielded higher certainty equivalents because of the higher cost of variable rate application. When variable rate costs were assumed to be zero, variable rate technology was profitable in

most cases. Variable rate technology did not appear to decrease risk associated with N management. Long-term nitrogen response functions from Illinois were used to test the economic benefit of greater uniformity in nitrogen application across the toolbar.

b. *Impact:* The analysis shows that in the long run over many crop seasons, the yield gains to greater N uniformity may be quite modest. For example, the analyses suggest a long-run gain of less than a half bushel per acre for a corn-soybean rotation. At current prices this modest yield gain may justify an investment in an improved manifold which would reduce the application rate variability by about half, but more expensive equipment which provides an almost uniform application may be difficult to justify on benefits of N uniformity alone.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Corn Belt

Key theme: Agricultural Profitability (1)

a. *Description:* This study has focused on food consumed away from home and food purchased at supermarkets. The nutritional quality of food consumers choose in restaurants is on average worse, especially with regard to calories, than food prepared and consumed at home. It is widely believed that this mainly applies to fast food, but this appears to be erroneous-- food obtained at non-fast food restaurants is on average no better and in many cases more nutritionally damaging than is fast food. A problem with the conventional wisdom is that it may have generated the view that as long as fast food is avoided, one need have little concern with nutrition when dining out. People with greater nutrition concerns and higher knowledge are less likely to consume fast food, but these factors have virtually no effect on use of table service restaurants. There is indirect evidence that nutritional information concerning food away from home is deceptive, and, given the fact that nutritional effects, especially calories obtained, from other types of restaurants may actually be worse, may be worsening the obesity problem.

b. *Impact:* There is no doubt that consumer food choices play a significant role in health and well being, a fact underscored by the growing problem of obesity. Much blame has been leveled at the restaurant industry, about which there is much negative publicity. However, nearly all of this is leveled at fast food, to the point of resulting in lawsuits against fast food firms. While there is considerable evidence that fast food diets are less nutritious than food eaten at home, the assumption on the part of many consumers is that food from standard restaurants is much better, especially with respect to calories. This study found this not generally true, even for children, primarily because people eat less at fast food outlets. We believe this reflects that diners must pay for all items individually. This finding is important because a second finding is that consumers more concerned with nutrition are more likely to avoid fast food and choose full service fare. To the extent this is a response to conventional wisdom, it is an information failure and a matter to be considered in setting food policy.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

Key Theme: Agricultural Competitiveness (1)

a. *Description:* This project analyzed the farm income stability implications of U.S. and EU agricultural policies over the past decade. The analysis clearly demonstrates that farm income stability is an important objective for both. Furthermore, the analysis shows that in both cases the policy sets used in the U.S. and

EU effectively achieve farm revenue stability. This has very important implications for trade negotiations. Economists generally advocate decoupled payments instead of coupled payments; that is, payments that are not linked in any way to current production or market price. Both the United States and the European Union use direct payments that are decoupled as part of their policy set. But in both cases, other policies provide revenue stability through coupled payments or other protective measures. Without protective measures or coupled payments, there is no way to ensure revenue stability, so government stability objectives run exactly counter to the trade preference for decoupled payments.

b. *Impact:* The major impact of this analysis is that developed and developing country governments alike now have a better understanding of the conflicts between reducing trade distortions and maintaining farm revenue stability. New policy approaches will have to be considered to satisfy the domestic and international trade policy objectives.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* Global

1F. Value-Added

Key Theme: Agricultural Competitiveness (1)

b. *Description:* The potential to capture wider profit margins of a value added corn product was evaluated through two different, but related analyses; a demand study and a simulation study to evaluate potential returns on investment. The demand study involved a mail survey of businesses in the food service industry that might purchase corn masa flour. A conjoint analysis of the survey was conducted for individual and aggregate customer models. Small purchasers of corn masa flour are willing to pay for superior service, such as consistent product quality, a price premium between 3 and 5 cents per pound. The demand survey also revealed a clear preference for corn masa flour from non-GMO corn. The simulation model was constructed to determine if corn masa flour production could provide a rate of return above all economic costs. Both deterministic and stochastic net present values were evaluated with risk introduced through varying prices of corn, corn masa flour, and varying demand. There is an opportunity for producer groups to earn a return above all economic costs by investing in a value added corn masa flour operation. However, there is also a 20 percent chance of business failure. Uncertain demand is the greatest factor affecting sensitivity of the results.

b. *Impact:* Producers are exploring new ways of conducting business including investment in value added processing of the commodities they produce, like corn. These research results are being incorporated into current decisions by producers, cooperatives, and other agribusiness leaders.

c. *Source of Federal Funds:* Hatch

c. *Scope of Impact:* Midwest

Key Theme: Adding Value to New and Old Agricultural Products (1)

a. *Description:* The overall goal of this project is to describe experimentally and by mathematical models the behavior of cereals during processing and the role that this behavior plays on their processing. The investigative work focused on describing physical and chemical changes of cereals, notably corn, subjected to a number of processes which include steam pressure cooking, tempering, drying and flaking. The effect of the addition of fibers to cereals on expansion during extrusion was also studied. Chemical

and physical changes of cereal notably during flaking operations play a fundamental role on the processing of these cereals and particularly in their final quality. Physical changes of cooked corn grits were monitored during tempering and drying using a rheological method developed in our laboratory (Broad Band Squeezing Flow). The instrument, along with the measurement of thermal effects by differential scanning calorimetry, was able to monitor the re-association of starch molecules upon tempering and drying. This re-association of gelatinized starch molecules, mainly amylopectin which is the branched fraction of starch, significantly affected the rheological properties of the grit prior to the flaking operation. Hence, these changes had a large effect on the processing of the cereal and its final quality. The latter was assessed by physico-chemical tests developed in our laboratories (e.g., water uptake, starch fragmentation) as well as sensory evaluation. The incorporation of fibers up to a content of approximately 22% was intended in an extrusion process that also included cornmeal. Against the general belief that the particle size of fibers significantly affects the extrudate expansion it was shown that this effect is negligible when compared to the effect caused by degree of crystallinity of the fiber. Results clearly showed that amorphous fibers or fibers with lower crystallinity have a positive effect on expansion and quality of cereals extruded in the presence of fibers.

b. *Impact:* New dietary guidelines recommend a higher daily consumption of fibers to prevent diverse forms of cancer and cardiovascular diseases. Breakfast and other cereal foods contain lower percentages of fibers because the addition of a high content of fibers to cereals results in products that are very dense, have a poor texture and are not very palatable. In an attempt to improve the high fiber dietary requirement of cereal foods without affecting their organoleptic properties, Purdue researchers are developing new processes to modify these fibers so that they can be added to food formulation (mainly for extrusion processes) in larger quantities.

c. *Source of Federal Funds:* Hatch

b. *Scope of Impact:* United States

Key Theme: Risk Management (1)

a. *Description:* H-MR CPMG-T2 tests were conducted on apples as they are moved through the magnet of a low-field (5.35 MHz) H-MR sensor at speeds from 0 to 250 mm/s. The T2 relaxation signals of healthy apples and apples with internal browning were distinctly different. Classification error was 12% or less at a conveyor speed of 50 mm/s, but at faster conveyor speeds it was as high as 38%. Precise and consistent positioning of the sample at the time the CPMG test is initiated are essential for minimizing classification errors. Results suggest that it would be possible to improve performance at higher speeds by modifying the magnet to provide greater pre-magnetization of the apples.

b. *Impact:* This research adapted a sensor for rapid and nondestructive measurement of fruit and vegetable quality or maturity. On-line magnetic resonance detection of internal browning or water core in apples could be used in a packing facility for removing defective fruit. This would improve product quality, increase customer satisfaction, and reduce losses.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

Key Theme: Biobased Products (1)

a. *Description:* The desire to control the processing and ultimate sale of farm commodities and to reap the full economic benefit from planting a seed to final product is common to many farmers and farm

organizations. From small roadside stands to major farm cooperatives, farmers have shown the initiative and resourcefulness to create rural-based enterprises through the investment of their own time and resources. In the case of soybean processing, capital investment for land, equipment and infrastructure can reach hundreds of millions or even billions of dollars. This project looks at much more limited investment levels using small expeller processing equipment to determine if minimum capital investments can return a profit. While not as economical as world scale plant complexes, such small scale facilities would retain advantages of using locally produced soybeans and selling to close by markets not being served by major producers. Within limits, small expeller plants should be able to operate profitably in large portions of the United States. However, there is a size limit below which any margin created by processing will not return a reasonable profit on labor. Conversion of expelled soybean oil into industrial products, such as biodiesel, will require a larger scale processing facility than the minimum scale required for profitable expelling. Fuel uses will vary in economic viability depending on the relative economics of soybean oil prices and energy. These uses will also be highly influenced by public policy toward energy, such as availability of incentives/tax abatements.

b. *Impact:* This project developed economic evaluation tools (spreadsheet simulations) of soybean expeller plants of different size scales to determine commercial potential for rural industry development. While technical/economic feasibility has been shown, commercialization requires resolution of issues such as transportation and commercial acceptance. Biodiesel production using conventional processing is economically attractive, however, the economics of scale strongly favor larger production facilities than investigated here. The use of glycerin from biodiesel production as a deicing fluid appears technically feasible and economically attractive. However, the technical, regulatory, and liability issues associated with deicer sales will likely preclude small farmer groups from selling finished formulated deicer products, and hence commercial partners should be sought.

c. *Source of Federal Funds:* Hatch

c. *Scope of Impact:* Midwest

Goal 2: SAFE AND SECURE FOOD AND FIBER SYSTEM

Overview: The safety and security of the U.S. food supply continues to be a very important public health and economic consideration for the food industry, regularity agencies, and consumers. For inherent food safety problems alone, the Centers for Disease Control and Prevention (CDC) estimates that 76 million cases of foodborne illnesses, 325,000 hospitalizations, 5,500 deaths, and costs of $7.7-$23 billion occur each year in the United States. Since September 11, 2001, the presence of intentionally added hazards (bioterrorism) has also become a key focus. Information and estimates relative to food defense risks are unknown, but, certainly the perceived risk and concern is very high. Food defense continues to be very high on the priority list of FDA and USDA. Outside of regularity requirements for food safety, the quality of the food supply is also a top concern for the food industry. Programs developed at Purdue University have focused on developing strong research-based programs, and whenever possible, developing complementary outreach programs to effectively communicate information to researchers, the food industry, regulatory agencies, and the general public. This report describes some of our efforts related specifically to food security, food pathogen protection, food quality and food handling. Our efforts related to food security have focused on animal carcass disposal and on developing mathematical models to simulate public health and economic impact of food defense scenarios. Food pathogen protection focuses mainly on improving pathogen detection technologies, developing intervention strategies for foods and food ingredients, and understanding the microbial ecology of plants, animals, and the environment. Our Center for Food Safety Engineering is a good example of multi-disciplinary research and outreach focused on microbial pathogen detection. Efforts related to food quality mainly focus on grain storage conditions and pest control.

Considerable effort is also dedicated to developing, delivering, and determining impact of food handling programs offered to retail food establishments.

Successes:

- Developed a computer-based Food Defense Simulation that models the food supply and estimates public health and economic effects of the virtual scenario.
- Contributed to production of report entitled, Carcass Disposal: A Comprehensive Review.
- Utilized novel chlorine dioxide gas technology, in a continuous process, for inactivation of foodborne pathogens on fruit and vegetable products.
- Studied factors that affect the microbial ecology and presence of Salmonella bacteria in pork.
- Developed a wide variety of food pathogen and chemical toxin rapid detection technologies including bioseparation and sample preparation techniques, enzyme–linked immunosorbant assay, polymerase chain reaction, light scattering, biosensors, biochips and bioluminescence for detection of Listeria monocytogenes, E. coli, Salmonella, Campylobacter, molds, PCB's and other toxins. Established a multi-disciplinary effort, called the Center for Food Safety Engineering, to help foster collaboration and integration of research and outreach.
- Development of Cooperative Agricultural Pest Survey for quarantined pests.
- Engineering of better ventilation systems and intervention strategies for grains during storage.
- Establishment of a comprehensive research and training program for retail food establishment personnel coupled with a retail food manager certification examination.

Benefits:

- The Food Defense Simulation brings together key stakeholders involved in food defense preparing them to make better decisions to lessen public health and economic impacts in the case of a real attack to the food supply. This approach also offers an excellent way to strengthen communication between the groups.
- The Carcass Disposal: A Comprehensive Review provides alternatives for the meat and poultry industry to consider for inherent and initial contamination of carcasses, which will significantly lessen economic costs.
- The use of chlorine dioxide gas treatments for food products provides a very strong antimicrobial treatment which leads to a safer food product and improved product shelf-life, at a minimal cost to the industry.
- Reduction of Salmonella in meat and poultry products has been an interest for the food industry and USDA for the past 10 years. Having a good understanding of colonization of Salmonella on farm will help to develop better methods to reduce the organisms as it is delivered to slaughtering facilities, ultimately reducing microbial levels on raw pork products.
- Faster and more accurate method development and diagnostic tools for detection of foodborne hazards, developed through the Center for Food Safety Engineering, provides an important tool for the food industry and regulatory enabling them to identify and investigate problems more quickly. This ultimately leads to a safer, higher quality, and better protected food supply.
- The Cooperative Agricultural Pest Survey for quarantined pests helps to identify and target pest control and pest management programs for ingredient and feed storage.
- Improved storage conditions and intervention strategies for grains will help to improve grain quality and storage shelf-life.
- Effective retail food safety training helps to improve food handling at retail food establishments, which, in turn reduces risk of foodborne illnesses associated with those establishments.

Resources:

Approximately $244,878 of Federal formula funds and $1.73 million of state funds plus 22.3 FTEs have been invested in Goal 2. This is a best estimate and these are not presented as auditable numbers.

Key Theme: Food Security (1)

a. *Description:* Our goal is to develop an Indiana Food Defense Preparedness and Response Exercise to help the State of Indiana become better prepared to lessen public health and/or economic impacts of an intentional act of bioterrorism to the food supply. Our team has developed an existing dynamic and configurable interactive model, and this model has been delivered as a real-time simulation to food companies, state/local government agencies, and other stakeholders that would be involved in food defense related issues. The focus of our program is to develop simulation models to meet the specific needs of Indiana. In doing so, we raise awareness of the vulnerabilities of the Indiana food industry along with the proactive/reactive measures that can be taken, create a better understanding of government procedures, introduce companies to government personnel that would be involved in the event of a terror attack, and better measure the impact of decision making in a "virtual food defense scenario".

b. *Impact:* Two Food Defense Simulations have been held at Purdue involving key stakeholders in food defense and food safety. The exercises have positively impacted our state's preparedness in responding to a food emergency. It has helped assess the systemic risk of the public health and economic impacts associated with the introduction and transfer of contaminants and agents in the entire food flow system. This has created a wonderful network force of industry and government professionals whose responsibilities include the well being of consumers and the public good and whose increased knowledge would improve Indiana's capabilities for deterring, detecting, responding to and recovering from food related emergencies that have the potential to negatively impact the economy and public health of Indiana and its citizens. This novel initiative allows us to fulfill both learning and engagement roles in our State as well as serve as a model for states nationwide in their preparedness for food defense.

c. *Source of Federal Funding:* Hatch and Department of Human Services

d. *Scope of Impact:* United States

Key Theme: Food Security (2)

a. *Description:* The United States faces a heightened sense of awareness of its vulnerability to the effects of disease, weather, and terrorism. Widespread, large-scale livestock deaths could result from any of the aforementioned causes. The carcass disposal challenges stemming from large-scale livestock deaths could prove daunting and require careful planning and action to prevent major food security problems and massive economic losses. A team of Purdue University personnel contributed to a report entitled, Carcass Disposal: A Comprehensive Review. The report was produced for the USDA-Animal and Plant Health Inspection Service (USDA-APHIS) by a consortium of collaborators that formed the Carcass Disposal Working Group. The group included personnel from the Kansas State University's National Agricultural Biosecurity Center, Texas A&M, Sandia National Laboratories, and Purdue University. The report contains information on a wide range of disposal technologies and policy issues including economics, regulatory issues, and environmental impacts.

b. *Impact:* The report, intended to serve as an indispensable resource for officials tasked with planning for safe and timely disposal of animal carcasses, has been requested by interested parties in the United States, Australia, Great Britain, and Canada. It has also been downloaded from the Kansas State University Food Safety and Security website more than 8,000 times. The level of expertise and research-based information involved in putting together the report is already shifting the current response approach of USDA-APHIS in major animal disasters.

c. *Source of Federal Funds: Hatch and* USDA-Animal and Plant Health Inspection Services

d. *Scope of Impact:* Multi-State

Key Theme: Foodborne Pathogen Protection (1)

a. *Description:* During the past two decades, more foodborne outbreaks have been associated with consumption of produce. Fruit and vegetable products, such as lettuce, onions, tomatoes, sprouts, berries and fruit juices, have all been associated with contamination and illnesses from organisms including Escherichia coli O157:H7, Salmonella spp., Listeria monocytogenes, parasites, and viruses. In response to these concerns and consumer demand, alternative microbial reduction strategies are needed. Gaseous chlorine dioxide has emerged as a potentially important antimicrobial agent with various applications in food storage and food processing. We have developed a batch system and a continuous system that allows us to bring different concentrations of chlorine dioxide gas onto fruit and vegetable surfaces. In these systems, we can also alter temperature, relative humidity and contact time. We have been very successful in optimizing system conditions for pathogen reduction (including Escherichia coli O157:H7, Salmonella spp., Listeria monocytogenes) on produce surfaces including green peppers, strawberries, apples, and cantaloupes, each leading to more than a 5-log reduction.

b. *Impact:* The use of chlorine dioxide as an alternative antimicrobial treatment for produce could have a significant public health, food quality, and economic impact for the food industry. The new technology, once optimized, will effectively reduce foodborne pathogens which minimizes the risk of foodborne illness. Reduction of spoilage organisms will enhance quality and lengthen product shelf-life.

d. *Source of Federal Funding:* USDA-CSREES, Food and Drug Administration, and National Science Foundation

e. *Scope of Impact:* United States

Key Theme: Foodborne Pathogen Protection (2)

a. *Description:* The presence of Salmonella is ubiquitous in livestock and livestock environments. This constant threat to food safety must be addressed. When swine are shipped to slaughter a high percentage of them start to shed Salmonella; this reaction is thought to be associated with the stress of transportation and mixing inherent in the process. As few as 4% may be positive for Salmonella on the farm, but that percentage can increase up to 40% at the slaughter house. Our lab is investigating the role of stress hormones and their interactions with Salmonella in the living pig.

b. *Impact:* Thus far our research shows that Salmonella can monitor their host's physiology and respond to the stress hormones it releases. This ability may allow Salmonella to take advantage of the low immune function typically found in animals under stress. We found that swine that are constant shedders of Salmonella have lower cortisol, a stress hormone, than those swine that do not constantly shed Salmonella. The impact of this finding is that management strategies can be developed to temporarily elevate cortisol if it proves to be effective in preventing Salmonella transmission during transport. Our research has also found that Salmonella can monitor and respond to elevated concentrations of norepinephrine, a stress hormone, and more easily infect swine. The impact of this finding is that it provides a mechanism by which Salmonella can become more virulent and it allows researchers a focus to develop strategies by which producers can lower the stress of mixing and transportation and thus reduce norepinephrine concentrations which will reduce Salmonella's ability to infect swine.

c. *Source of Federal Funding:* Hatch and USDA-Agricultural Research Service

d. *Scope of Impact:* Multi-State

Key Theme: Foodborne Pathogen Protection (3)

a. *Description:* Identification of microbial foodborne contaminants, such as E. coli O157:H7, is a primary food safety concern in food production, processing, and retail environments. Improving the speed and accuracy of detection methods could prevent distribution and/or sale of foods containing pathogenic microorganisms. We developed an approach to improve the speed and accuracy of detection of E. coli O157:H7 using Fourier transform infrared spectroscopyand chemometrics. We investigated whole cells and extracted cell wall components from five E. coli strains (E. coli K12, E. coli DH5a, E. coli O157:H7, E. coli O157:H12, and E. coli O157:H19) using a deoxycholic acid-polyacrylamide gel electrophoresis method and Fourier transform infrared spectroscopy. The developed method successfully differentiated the E. coli strains using Fourier transform infrared spectroscopy spectra of intact E. coli cells (80% accurate) and isolated crude E. coli LPS extracts (100% accurate).

b. *Impact:* We successfully differentiated and classified the E. coli strains using the Fourier transform infrared spectroscopy spectra of E. coli crude LPS extracts in combination with multivariate statistical analysis. This study indicated that the Fourier transform infrared spectroscopy technique could be more useful for taxonomical or epidemiological investigations than LPS pattern analysis based on the level of speed, sensitivity, and accuracy. We are the first to report the discrimination of E. coli strains at a serotype level using Fourier transform infrared spectroscopy spectra of isolated bacterial phenol-phase extracts (crude LPS preparations). This approach can be used to facilitate bacterial identification for food safety applications, including investigations of food poisoning outbreaks or adulteration.

c. *Source of Federal Funding:* Hatch and USDA-Agricultural Research Service

d. *Scope of Impact:* United States

Key Theme: Foodborne Pathogen Protection (4)

a. *Description:* Rapid detection of food pathogens is needed to ensure a safe food supply and to enable detection of Listeria monocytogenes before this harmful organism reaches the consumer. Rapid construction of a microfluidic biochip has been further simplified so that it can be used for training of undergraduate students, and for providing an example of how microfluidic devices are constructed and used. In addition, this work has been further extrapolated in order to chemically bond enzymes to gold wire, with the goal of carrying out consecutive enzyme reactions at a nanoliter scale. The methodology is currently being tested by other laboratories nationwide.

b. *Impact:* This new method of designing chips, provides a rapid prototyping tool that utilizes very small amounts of reagents and proteins. This methodology will allow different chemistries and different reactions to be tested in order that new process concepts for microfluidic devices may be rapidly developed, and ultimately constructed using more traditional microfabrication techniques providing rapid detection of food pathogens. This device has been used to count E. coli cells, and also to map microfluidic flows in channels having volumes of less than 100 nanoliters. In addition, the methodology has been extended to carry out enzyme reactions in an observable manner in the microfluidic device. They lead to very small biosensors in which sequential biochemical reactions are used to detect molecules which serve as biomarkers for various types of microorganisms.

c. *Source of Federal Funding:* Hatch and USDA-Agricultural Research Service

d. *Scope of Impact:* United States

Key Theme: Foodborne Pathogen Protection (5)

a. *Description:* We have developed a procedure for immobilizing live bacteria (Listeria monocytogenes) on the surface of a glass slide and assessing their viability using a live/dead assay. Current work is focusing on making antibody to antigen binding measurements under various environmental conditions, e.g., pH, ionic strength, etc., to optimize binding strength. Our group is also working on improving methods of immobilizing sensing molecules, i.e., enzymes or antibodies, to improve stability, activity, and/or specificity to the target analyte or antigen. Selected oligomers and photo initiators were examined for the immobilization of an inexpensive model enzyme, glucose oxidase, on glass low density polyethylene and high density polyethylene as the support material.

b. *Impact:* The improved understanding of antibody-antigen interaction and the effects of environmental parameters can ultimately be used to design more sensitive and rapid biosensors for detection of low levels of contaminants in food products. If our work with antibodies for the food-borne pathogen Listeria is successful, detection limits will be improved and the time required for testing will be shortened. Ultimately, an improved sensor which can be used in a processing facility to monitor levels of Listeria in the plant may be possible. Early monitoring and detection of pathogen presence can give a warning sign prior to the contamination of food products.

c. *Source of Federal Funding:* Hatch and USDA-Agricultural Research Service

d. *Scope of Impact:* Multi-State

Key Theme: Foodborne Pathogen Protection (6)

a. *Description:* Research was done to characterize rapid methods to detect mycotoxin-producing molds in foods and to develop predictive models for death of pathogens in foods. Currently, about 100,000 spores of Fusarium graminearum and 1 million spores of Fusarium verticillioides can be detected. Our methods, using enzyme-linked immunosorbant assay (ELISA) and polymerase chain reaction (PCR), are being further optimized to be able to detect lower levels of spores (<100). A mathematical model has also been developed to predict how L. monocytogenes reacts to temperature when heated in hot dog broths with different levels of two preservatives currently used in processed meats. This research answers questions about how L. monocytogenes responds to 55, 60 and 65 C in processed meats with different levels of sodium lactate (0, 2.4 or 4.8% wt/vol) and sodium diacetate (0, 0.125, or 0.25% wt/vol). The inactivation of L. monocytogenes was affected by the temperature where an increase from 55 to 65 C increased death, by the type of preservative where sodium diacetate produced most death. A post process treatment for packaged hot dogs at 60 C for 10.8 to 19.6 min reduced L. monocytogenes by 1000 fold with the maximum decrease in 15 min at 60 C being from 2.3 to 5.1 log reductions depending on the treatment, strain and growth medium.

b. *Impact:* The research on the development of a protocol to release DNA from mold spores suggests that if this method can be further optimized, then a rapid method for mold detection can be developed and used in grain and food products. The predictive model for post-process killing of Listeria monocytogenes in hot dogs was submitted to the USDA to add to the Pathogen Modeling Program and to ComBase, which are computer programs maintained at the USDA website that can be used by the meat industry to develop

thermal processes for their products. Using this method, meat processing companies could use a predictive model to determine what heat or preservative treatment to give packaged ready-to-eat hot dogs and processed meats to kill L. monocytogenes if it were to contaminate the meat after processing.

c. *Source of Federal Funding:* Hatch and USDA-Agricultural Research Service

d. *Scope of Impact:* United States

Key Theme: Foodborne Pathogen Protection (7)

a. *Description:* Persistent pollutants, like PCBs and mercury, continue to pose a health risk to consumers of sportfish and commercial fish as demonstrated by the issuance of federal and state fish consumption advisories for sensitive populations. A limitation that occurs when developing advisories relates to the cost for collecting and analyzing fish for pollutants. We developed a number of multiple regression models to predict toxicity. We have also developed a more rapid analytical method for measuring selected PCB congeners in fish tissue and we have conducted studies to find the influence of selected foods on mercury bioaccessibility. This research has demonstrated the effectiveness of a more rapid method for the measurement of these congeners which can predict TEQ in fish tissue.

b. *Impact:* This research describes lower cost, rapid methods for measuring selected PCBs congeners in order to predict toxicity in fish tissue. This assay will assist in efforts to develop fish consumption advisories for recreationally-caught fish and will help regulatory agencies survey commercial fish products. In addition, our efforts will help sensitive populations, i.e., pregnant or nursing women and young children, to make an informed decision concerning their fish consumption. Finally, we have developed a better understanding of the dietary factors that influence bioavailability of methylmercury.

c. *Source of Federal Funding:* Hatch and National Institutes of Health

d. *Scope of Impact:* Multi-State

Key Theme: Foodborne Pathogen Protection (8)

a. *Description:* The Center for Food Safety Engineering was established to develop improved methods for hazard detection and better ways to control hazards in our food system. These goals were obtained by building research teams through collaborative efforts of five different schools including agriculture, consumer and family sciences, engineering, science, and veterinary sciences. Faculty teams are working on methods to detect pathogenic bacteria, molds and seafood toxins, and teams working on bioluminescence techniques that use infrared sensors. Some of the ongoing Center for Food Safety Engineering projects include:

a. Engineering of biosystems and development of a biochip and biosensors for the detection of Listeria monocytogenes in foods
b. Detection of specific foodborne pathogens using bioluminescence
c. Detection of Fusarium species in grains and foods by ELISA and PCR
d. Light scattering sensory method for rapid assessment of foodborne bacterial contaminants
e. Bioamplification using phage display for the detection of Salmonella spp.
f. Use of Fourier transform infrared spectroscopy for detection of Salmonella, E. coli, and Listeria monocytogenes

b. *Impact:* The development of bacterial pathogen detection methods that are more accurate and more rapid, will allow food processors and food regulatory agencies to identify potential problems more quickly. This technology could be easily applied for detection of potential biosecurity threats, which would help in response and recovery efforts.

c. *Source of Federal Funding:* Hatch, USDA-Agricultural Research Service, National Institutes of Health, Food and Drug Administration, and National Science Foundation

d. *Scope of Impact:* Global

Key Theme: Food Quality (1)

a. *Description:* An extensive and intensive effort to monitor, review, and acquire information on the significant 20-22 quarantined pests would be of value to Cooperative Agricultural Pest Survey and its extended community. In this regard, National Agricultural Pest Information System staff act as a liaison between the federal and state communities coordinating information on quarantined pests by contacting the state departments of agriculture, the state extension agencies, and the state universities to determine what survey efforts are being conducted and working to bring all of the relevant information into the National Agricultural Pest Information System.

b. *Impact:* Review of the pests species recorded for Indiana in National Agricultural Pest Information System indicated that the major focus of the Cooperative Agricultural Pest Survey programs to date have been centered toward insects, followed by pathogens, weeds, nematodes, and invertebrates. Insects constitute approximately 80% of the total recorded species for the state of Indiana and account for 60% of the species in National Agricultural Pest Information System database for Indiana. Alfalfa weevil, Gypsy moth, and European corn borer account for the greatest number of total records for insects. For nematodes, soybean cyst nematode accounts for the greatest number of total entries and water milfoil accounted for the greatest number of records for weed species in Indiana.

c. *Source of Federal Funding:* Hatch

d. *Scope of Impact:* Multi-State

Key Theme: Food Quality (2)

a. *Description:* We have implemented and tested an optimized version of the self-adapting mode of the fan and burner controller for temperature drying systems for grains. Our new approach using a Self-Adapting Variable Heat strategy was developed and implemented in the field. This strategy was designed to self adapt its settings according to the history of the weather pattern during the drying season. The goal of this new strategy was to maximize the fan run time in any weather condition, while avoiding the over drying of the grain bottom layers. The new Self-Adapting Variable Heat strategy properly identified different weather patterns and self adapted its settings accordingly. As a result, the fan run time was maximized (range of fan run time was from 95 to 100% for the four Self-Adapting Variable Heat experiments). Upon modifications, our results showed that our methods were able to predict moisture content change with a significantly lower standard error ranging from 0.44 to 0.70%.

b. *Impact:* This project involves simulation analysis and applied research to evaluate less detrimental technologies, such as low temperature and combination drying, and chilled grain aeration and conditioning for a range of cereal grains and oilseeds, for implementation on farms and at commercial facilities. Modeling work primarily focuses on improving the accuracy (using the finite element and finite difference numerical methods) and expanding the adoption of the Purdue Post-Harvest Aeration &

Storage Simulation Tools into computer-based commercial grain management systems. Applied research is primarily conducted in the pilot-scale storage structures of the Purdue University Post-Harvest Education & Research Center, and in full-scale systems of collaborating producers, handlers and processors. The refinement and field testing of the self-adapting variable heat fan and heater control system is currently being incorporated into a commercial application. It is expected to be introduced for the 2006 crop drying season.

c. Source of Federal Funding: Hatch

d. Scope of Impact: Multi-State

Key Theme: Food Quality (3)

a. Description: Our research focuses on evaluating the efficacy of ozone as a new tool for the management of stored food grains. The goal of the current research is to test this technology under field conditions in farm-scale bins for two food grains (food corn, popcorn) at two locations (Indiana, Illinois) during two consecutive storage seasons (2005, 2006). This study is being conducted by a multidisciplinary team at Purdue University in collaboration with a corporate sponsor which manufactures large-scale ozone generators. This year's research indicates that insect mortality is very high (92-100% mortality) when fumigated with 50 ppm ozone for three days. Another area of research involves the comparison of a newly labeled fumigant versus one that is being phased out. As a result of the Montreal Protocol, methyl bromide, a major fumigant for the food industry, is facing a mandatory 100 percent production and import phase out. Millers, food processors and fumigators are looking for replacements. Sulfuryl fluoride, is one replacement strategy that was recently labeled for the food market. This study is being conducted to examine the effectiveness of sulfuryl fluoride under real world conditions. To date, two fumigations have been conducted in two separate flour mills. Two pest species, Indianmeal moth, Plodia interpunctella (L) and red flour beetle, Tribolium castaneum (Herbst) and all life stages were used in bioassays during the 24 hour fumigations. Trapping (pheromone and dome traps) was conducted before and after the fumigations to determine the existing pest population and rebound. Preliminary results indicated 100% mortality of larval, pupal and adult stages of both species. Mortality of egg stage is still under observation.

b. Impact: Optimization and use of this technology in the field could dramatically improve storage conditions for grain products. This, in turn, would increase yield and produce animal feed and human food ingredients with increased quality.

c. Source of Federal Funding: Hatch

d. Scope of Impact: Multi-State

Key Theme: Food Quality (4)

a. Description: Low carbohydrate foods and ingredients are very popular. The objective of these experiments was to determine the effect of xylitol, soy protein isolate, inulin, and resistant starch on the cooking properties of corn starch and to determine the feasibility of preparing a muffin containing these ingredients replacing 50% of the flour and 50% of the sucrose. RVA analysis of corn starch was carried out in the standard way except that xylitol, soy isolate, inulin, or resistant starch was added as well. Control muffins were prepared by a standard recipe. Test muffins had 50% of the flour replaced with soy isolate (20%), inulin (20%) and resistant starch (10%). Muffins were stored for 5 days and texture, water activity, and color measurements were taken. RVA experiments showed that increasing amounts of soy isolate, xylitol, or resistant starch increased the peak and final viscosities obtained. Inulin showed the

opposite behavior that is a decrease in peak and final viscosities with increasing inulin concentration. Texture values for control and treated muffins were not statistically different at any time point and water activity was only statistically significant at day 2. Hunter L (34.8 vs. 22.3), a (16.1 vs. 12.4), and b (17.3 vs. 9.3) values were highly significantly different between the control and test muffin. It is clear that ingredients affect starch gelatinization and this must be taken into account in formulating baked goods. The interesting effect of inulin requires further investigation. Muffins containing 50% less flour and sucrose can be formulated which are not significantly different in texture or water activity from the control muffin. The test muffins are however significantly darker and variations in cooking time may be required to produced a muffin closer in appearance to the control.

b. *Impact:* Low carbohydrate foods have seen an explosive growth in recent years, due largely to diets such as the Atkins diet. Today, millions of Americans are trying to reduce their intake of calories, sugar, and fat. High intake of sugar is associated with increased risk for obesity, diabetes, kidney stones, osteoporosis, heart disease, and dental caries. Additionally, proponents of the Atkins diet suggest that low intake of carbohydrates is positively associated with weight loss. This set of experiments was undertaken to examine the effect of these non-carbohydrate or low digestibility carbohydrates on the gelatinization of starch and to see the effect of substituting these ingredients in a muffin recipe to replace 50% of the sucrose and 50% of the wheat flour. It appears that increasing the amount of non-carbohydrate or non-digestible carbohydrate ingredients generally increase the viscosity values of cooked corn starch. This may have significant effects in food processing of such mixtures. Incorporation of such ingredients into a model food system such as muffins makes no difference in the texture of the muffins and only a minor effect on the water activity. However, there were color differences between the test and control muffins that would have to be accounted for if such a muffin were to be made and marketed as a low carbohydrate food.

c. *Source of Federal Funding:* Hatch

d. *Scope of Impact:* Multi-State

Key Theme: Food Handling (1)

a. *Description:* Foodborne illness continues to be an important concern for consumers nationwide. CDC estimates that between 76 million cases of foodborne illness, 325,000 hospitalizations, 5500 deaths, and costs of 7.7-23 billion dollars may occur each year. Many of these reported foodborne illnesses have been attributed to the retail portion of the food production chain including food establishments such as restaurants, institutions, supermarkets, and convenience stores, etc. One of the important keys to prevent foodborne illness is through effective education and training for retail food establishment employees. As of January 2005, Indiana now requires at least one retail food manger from each retail food retail establishment be certified in retail food safety and pass a nationally recognized exam. Our program focus is to prepare retail food managers for this requirement and teach sound food handling procedures. Three programs are offered in Indiana to address these needs including ServSafe, Essentials of Food Safety and Sanitation, and SuperSafeMark. Each program has been developed as a nationally recognized curriculum and certification program for retail food handlers. Each program is designed as an 8-hour or 16-hour program for retail food managers and is linked with a retail food certification exam developed by the National Restaurant Association of the National Registry of Food Safety Professionals. The target audience includes retail food managers and retail food workers. The program is also offered to corporate trainers and academic trainers that serve the retail food industry.

b. *Impact:* Within Indiana, the program is offered through Purdue University (Essentials of Food Safety and Sanitation and SuperSafeMark programs) and with the Indiana Restaurant and Hospitality Association

(ServSafe program). Within Indiana, over 5,000 people were certified during the reporting year. Each program is offered through a partnership with local health department staff. Demographic data indicates that the majority of participants are at the management level (35%), are at least high school graduates (52%), have worked in food service 3 or more years (74%), and are Caucasian (87%). 4.1%, 3.1%, and 2.1% represent Hispanic, African American, and Asian participants. Data from our programs indicate that improvement is being made relative to safe food handling practices such as hand washing (36%), time and temperature control (32%), cross-contamination control (34%), cleaning and sanitation (31%). More participants (29%) are now also conducting food safety training in their food establishments. This retail food safety curriculum satisfies an important training need for retail food managers. The training should reduce the risk and likelihood of foodborne illness and improve food-handling practices in retail food establishments.

c. *Source of Federal Funding:* Hatch, USDA-CSREES, FDA

d. *Scope of Impact:* Indiana

GOAL 3. A HEALTHY, WELL-NOURISHED POPULATION

Overview: Diet and nutritional concerns are a high priority in the United States, especially obesity. The health of the nation is dependent on the availability of high-quality, nutritious foods and the ability of the public to make good dietary choices. Diet is one of the most significant factors influencing the health of individuals. To ensure continued improvements in the well-being of the public, a deeper understanding of nutritionally affected metabolic pathways and a better understanding of dietary intake controls are essential. With this knowledge, better nutritional and dietary guidelines can be designed and new foods with improved or added benefits can be developed. Purdue University researchers have conducted basic nutritional biochemistry research, identified and quantified constituents of a healthy diet, identified foods or dietary components that will improve deficiencies or prevent future health problems, and developed raw or processed foods with traits that add both nutrition and value to current diets. This work will lead to a healthier, better-informed public capable of making choices among a wide variety of nutritious and functional foods and dietary supplements.

Purdue University researchers have made great strides in identifying natural food components that have nutritional benefits, and to providing dietary guidance to lower the risks of developing certain health problems in humans. Nutrition scientists, food scientists and plant biologists are working to develop better ways to manage a variety of factors that affect health. Purdue researchers work to deliver dietary guidance in partnership with Purdue Extension and various state and national health organizations. This cooperation provides both a means of delivery to the public and a pathway for identification of future research needs.

Calcium and Vitamin D: Purdue University scientists are national leaders in calcium and bone research. The metabolism of calcium in adolescent boys is quite different than in adolescent girls. Metabolic studies conducted at Purdue University have shown that calcium retention in boys is higher from a given food than it is in girls. Boys are more efficient in using dietary calcium than girls. Implications of this increased calcium retention efficiency in boys, is seen in the size and density of male bone as compared to female bone. These results have been used to determine the recently revised national dietary requirements. Research also has suggested that there may be differences in calcium absorption among people with diverse ethnic backgrounds or genetic diversity.

Vitamin D, also a factor in adequate calcium absorption, has many other roles in the human body. Normal cells have very tight regulatory mechanisms for growth control and programmed cell death. Cancer is a state where cell growth and programmed death has been changed dramatically from normal. Studies have shown that the active form of Vitamin D (1, 25$(OH)_2$D) inhibits cell death in normal cells, but not in cancer transformed cells.

Understanding the mechanisms of how Vitamin D regulates cell growth and death could ultimately lead to dietary recommendations to reduce the risk of cancer.

Carbohydrates in health: Studies conducted on methods to moderate starch digestion rate in processed food have resulted in two potentially useful findings. This first is a new process of controlled starch digestion to produce slowly digested starches with food rheological properties. Secondly, the mechanism for the slow starch digestion property seems to be a protein starch interaction which can be created in other cereal flours. These slowly digested starches produce low -lycemic responses and may have implications to diabetes, pre-diabetic condition, and possibly obesity.

Horticulture researchers understand the importance of the nutritional value of fruits and vegetables. Tomato fruits containing several fold higher levels of lycopene have been produced at Purdue University. The bioengineered tomatoes exhibited a three fold increase in lycopene, showed juice quality indicators 50% higher than non-transgenic tomatoes, and were able to stay on the vine significantly longer than parental non-engineered fruits.

Diets higher in fiber in foods have been linked epidemiologically with lower incidence of some chronic diseases, most notably colon cancer. Purdue researchers are investigating the impact of psyllium to modify hepatic gene expression. Hepatic enzymes that regulate the production of cholesterol are targeted for investigation.

Health and aging: Selected brain receptors are putative targets for protein phosphatase 5 regulation in non-neuronal cells and are critical in nervous system development, stress responses and aging. Purdue University scientists are investigating whether protein phosphatase 5 and glucocorticoid receptors are co-localized at the cellular level within these brain regions. Protein phosphatase 5 has been shown to be an important tau phosphatase in brain. Since tau phosphorylation is thought to be important in the neurodegenerative processes underlying Alzheimers disease, Purdue University research suggests that protein phosphatase 5 activity in neurons could help prevent the degenerative processes that lead to this debilitating disease associated with aging.

Successes:

- Understanding of the function and regulation of the protein phosphatase 5 in the central nervous system may lead to a better understanding of the causes and cure of Alsheimer's disease.
- Phytochemicals such as non-nutrient flavonoids in fruits and vegetables may help prevent chronic diseases.
- Dietary calcium and vitamin D can promote weight loss and bone health.

Benefits

- Soy-based foods in combination withn-s polyunsaturated fatty acid (typical of a Japanese diet) may increase bone health.
- Slowly digestible, low-glycemic starches have been extracted from corn that can impact the "metabolic syndrome" of obesity, diabetes, and cardiovascular disease.
- Fortified soymilk is as good a source of calcium as cow's milk.
- Eat Move Learn, a web-based program, is helping school children reduce obesity and the risk of diabetes and cardiovascular disease.
- Both nutrition and exercise are essential for health and functioning of older people.

State Assessment of Accomplishments:

Research under this goal is addressing public needs in terms of improving the health and well-being of the citizens in Indiana and beyond. Research has clearly demonstrated ways to reduce the risk of cancer, lower the incidence of osteoporosis, and address obesity issues. Citizens are provided information regarding potential health impacts of their food choices through Extension education programs and websites.

Resources:

Approximately $288,310 Federal formula funds and $2.31 million of state funds plus 22.6 FTEs have been invested in Goal 3. This is a best estimate and these are not presented as auditable numbers.

Key Theme: Human Health (1)

a. *Description:* The long-term goal is to understand the function and regulation of protein phosphatase 5 in the central nervous system. Studies have shown that protein phosphatase 5 is expressed primarily in neurons of adult rat brain, since it was co-localized with h-Nu, a neuronal marker, but not with glial acidic fibrillar protein, a glial cell marker. Protein phosphatase 5 dephosphorylates tau which is found in a hyperphosphorylated state in neurofibrillary tangles characteristics of diseased neurons in Alzheimer's patients. To further investigate the relevance of tau dephosphorylation by protein phosphatase 5 to Alzheimer's disease, it was demonstrated that protein phosphatase 5 acted on specific tau sites known to be hyperphosphorylated in Alzheimer's disease.

b. *Impact:* Protein phosphatase 5 is involved in mediating hormonal regulation of ion channel function and implicates protein phosphatase 5 as an important phosphatase for tau, which is hyperphosphorylated and concentrated in neurofibrillary tangles in diseased neurons of Alzheimer's patients.

c. *Source of Federal funding:* Hatch

d. *Scope of Impact*: Global

Key Theme: Human Health (2)

a. *Description:* During the past year progress has been made in understanding the potential antioxidant mechanisms of flavonoids in vivo. The addition of the green tea phytochemical epigallocatechin gallate at 30 mg/kg to diets deficient in vitamin E and selenium partially protected the animals from developing deficiency symptoms. A dose-response experiment in rats under high versus low oxidative stress conditions that were created by feeding weanling rats (n=6-8/group) diets adequate in vitamin E and selenium, or deficient in vitamin E and selenium for six weeks was conducted. The effect of epigallocatechin gallate was tested by adding the purified flavanone to the diets at four different concentrations (0, 30, 60, or 120 mg/kg diet) in a 2X4 factorial design. The epigallocatechin gallate appears to function as an antioxidant in vivo via an interaction with vitamin E, which has been shown to occur in vitro

b. *Impact:* Our work on phytochemicals suggests that the non-nutrient flavonoids, rich in fruits and vegetables, may exert their protective antioxidant action through increasing the endogenous antioxidant defense system. Further refinement of this information could lead to specific recommendations for fruit and vegetable intake to help prevent chronic diseases.

c. *Source of Federal funding:* Hatch

d. *Scope of Impact*: United States

Key Theme: Human Nutrition (1)

a. *Description:* Hypoestrogenic states escalate bone loss in animals and humans. Our investigations evaluated the effects of the amount and ratio of dietary n-6 and n-3 polyunsaturated fatty acids on bone

mineral in 3-month-old sexually mature ovariectomized Sprague-Dawley rats. For 12 weeks, rats were fed either a high or low polyunsaturated fatty acid diet with a ratio of n-6/n-3 of 5:1or 10:1. This study indicates that the dietary ratio of n-6/n-3 of 5:1 and bone tissue concentration of total long chain n-3 polyunsaturated fatty acids minimize femur bone loss.

b. *Impact:* A lower ratio of these fatty acids in tissue correlates with reduced bone resorption and higher bone formation markers and bone mineral content values that favors bone conservation in the estrogen-deficient rat. These findings indicate a complementary action of soy containing foods in combination with n-3 polyunsaturated fatty acid (typical of the Japanese diet) for bone health.

c. *Source of Federal funding:* Hatch

d. *Scope of Impact*: United States

Key Theme: Human Nutrition (2)

a. *Description:* The focus of this study is on conjugated linoleic acid and its effects on lipid metabolism and gene expression. Recent experiments involved thirty-two female Sprague Dawley rats (21 days of age) which were randomized to diets containing either 10% control butter or 10% linoleic acid enriched butter. After six weeks, rats were killed and liver samples adipose tissue samples were taken for lipid analysis and mRNA transcript profiling. There was no difference between the two groups in body weight gain. Liver lipid analysis showed that linoleic acid as a percentage of total liver fatty acids was elevated 5-fold in linoleic acid group compared with the controls. Feeding linoleic acid elevated mRNA abundance of hepatic fatty acid synthase by more than 400%, and acyl-CoA oxidase by 227%. In adipose tissue, however, mRNA abundance of neither enzyme was different between the two groups. The data indicate that milkfat that is enriched with linoleic acid acts as a functional food to impart biological effects to change liver fatty acid profile. Its effect on expression of genes involved in lipid metabolism in growing rats appears to be specific to liver.

b. *Impact:* There is evidence that linoleic acid may reduce the risk for development of atherosclerosis. The mechanism for such an effect has not been elucidated. Our studies suggest that the effects of linoleic acid are not consistent in the various strains of experimental animals or in various tissues. These data suggest that we should proceed with caution in making recommendations for inclusion of linoleic acid in human diets until we understand if benefits should be expected from such dietary changes.

c. *Source of Federal funding:* Hatch

d. *Scope of Impact*: United States

Key Theme: Human Nutrition (3)

a. *Description:* Acute and chronic feeding studies were conducted on the effect of purported calcium absorption enhancing components on calcium absorption and retention and bone measures in growing rats. Whey protein and honey and its constituents enhanced calcium absorption in a dose response manner in single meal experiments, but the effect largely disappeared on chronic feeding attributable to adaptation through the calcium homeostatic mechanism.

b. *Impact:* Calcium intake is well below recommended levels for most people above age 9. Calcium utilization may be altered by certain ingredients. Whey proteins and honey appeared to be good enhancers

of calcium utilization in a single meal, but conferred little benefit in long term feeding. Fortified soymilk was as good a source of calcium as cows' milk.

c. *Source of Federal funding:* Hatch and National Institute of Health

d. *Scope of Impact*: United States

Key Theme: Human Nutrition (4)

a. *Description:* A web-based program, Eat Move Learn, has been developed as four modules called Explorations. Explorations meet many of the National Science Education Standards, set forth by the National Committee on Science Education Standards and Assessment of the National Research Council. In Exploration, students make predictions about their movement, use pedometers to measure their steps, draw conclusions, and make recommendations on how to sustain increased activity. Students can determine the relationship between caloric consumption (energy in) and movement/activity (energy out). They can look at two tools scientists use to determine how much energy a person burns doing different activities, and how many calories are in a given food item. Students work in groups as anthropologists, physiologists, or nutritionists to examine why America is out-of-shape. The groups make conclusions regarding the primary contributors to America being out of shape based on the ecological model of health behavior that addresses intrapersonal factors, the social and cultural environment, and the physical environment. To evaluate the Eat Move Learn program, 6th grade schools within an hour radius of Purdue University and the University of Arizona were invited to participate.

b. *Impact:* The reduction and prevention of overweight among adolescents and young adults may decrease the occurrence of diabetes and cardiovascular risk factors

c. *Source of Federal funding:* Hatch

d. *Scope of Impact*: United States

Key Theme: Human Nutrition (5)

a. *Description:* Osteoporosis is the most readily identifiable health issue associated with inadequate calcium intake. Obtaining sufficient calcium during adolescence helps ensure adequate mineralization of the skeleton to ensure bone health later in life. Results obtained from a previous multi-state project highlighted that familial factors play an important role in the calcium intake of youth. However, little information is known about these factors. Therefore, 13 states are actively examining parental factors such as knowledge, attitudes, behaviors, and environment and their influence on calcium intake of children in early adolescence (11-14 years old) from race/ethnic groups most at risk for osteoporosis. A questionnaire to assess parental influences on the calcium intake of their early adolescent children was drafted and pre-tested with 5-6 parents at 10 of the project sites. Principal component analysis will be used to assess the internal validity of the psychosocial scales identified by the parental questionnaire.

b. *Impact:* The results from this multi-state project will be used to identify factors that influence the calcium consumption of early adolescents. The information can be used to design effective, tailored nutrition intervention for early adolescents and their parents. The messages found effective for improving bone health, may also be useful for minimizing the development of obesity.

c. *Source of Federal funding:* Hatch and National Institute of Health

d. *Scope of Impact*: United States

Key Theme: Human Nutrition (6)

a. *Description:* This study documented water balance, hydration status, and fat-free mass hydration in young and older adults. Older adults maintain water input, output, and balance comparable to those of younger adults, and have no apparent change in hydration status. Hydration of fat-free mass is increased in older men and women. The integrative effects of diet and exercise on the health of older people was evaluated as to whether the predominant source of dietary protein influenced the lipid-lipoprotein profile in older men who performed resistance exercise training for 12 weeks. The major protein sources were either beef or soy. The lipid-lipoprotein profile of older men was differentially affected by supplementation with beef versus soy-based foods during resistance training. Changes in lipid-lipoprotein profile were predicted by differences in the saturated fat to fiber ratio and cholesterol to fiber ration and increases in carbohydrate intake over time.

b. *Impact:* Both nutrition and exercise are important for the health and functioning of older people. Healthy older people are able to maintain some aspects of health comparable to younger adults, e.g., water balance and hydration status. Nutrition and exercise interventions can improve risk factors associated with chronic diseases, e.g., lipid-lipoprotein profile and markers of inflammation.

c. *Source of Federal funding:* Hatch and National Institutes of Health

d. *Scope of Impact*: United States

Key Theme: Human Health (1)

a. *Description:* Our laboratory focuses on the effect of dietary calcium and vitamin D on fat and bone mass. Higher intakes of dairy products incorporated into a weight loss diet caused a two-fold increase in fat mass loss in overweight and obese individuals. The results also demonstrate that calcium supplementation during weight loss promotes fat oxidation (burning) following a meal. Further, the baseline vitamin D status correlates with the change in fat oxidation, independent of the calcium intakes during the study, suggesting that vitamin D status may lead to alterations in energy expenditure. In another calcium educational multi-site trial, calcium intake in adolescents was negatively associated with trunk fat and waist circumference; thus the higher the intake of calcium, the lower the fat mass. Further, increased dairy product intake over a year long intervention lead to no change in weight or fat mass in normal weight young women. However, the higher dairy product intakes caused an increase in fat oxidation in normal weight young women, and the change in parathyroid hormone, which is regulated by both vitamin D and calcium, was associated with change in fat oxidation, independent of calcium intake. In this cohort, higher intakes of calcium also prevented bone loss in women consuming oral contraceptives.

b. *Impact:* Obesity is on the rise and now considered a national and global epidemic. It is estimated that obesity costs the United States $100 billion annually. Obesity is also a risk factor for serious chronic diseases. Diet plays a major role in the development of obesity, and while much effort has been devoted to studying the effects of macronutrients on weight control, the role of micronutrients has not been studied as well. The results from our laboratory which have investigated the impact and the underlying mechanism of dietary calcium and vitamin D on body fat mass contribute to knowledge for designing public health recommendations to prevent and treat obesity as well as strategies for cancer prevention.

c. *Source of Federal funding:* Hatch and National Institutes of Health

d. *Scope of Impact*: United States

GOAL 4: GREATER HARMONY BETWEEN AGRICULTURE AND THE ENVIRONMENT

Overview: The impact of work conducted under Goal 4, is found in our continuing support of Indiana's citizens as they work towards achieving an improved environmental quality for the state. Purdue researchers continue to develop and test solutions to allow for enhanced environmental protection of our land and natural resources and water supplies. This work is of critical concern to Indiana's agricultural sector and rural population, as enhanced environmental protection will allow for continued agricultural production in the light of increasing state and federal environmental regulation.

Animal Waste Management and Air Quality- Reducing the environmental impact of animal agriculture through economically feasible means continues to be a significant part of Purdue's environmental research efforts. Purdue is now the central location for a national effort to provide new methods and models for the management of air emissions from animal waste.

Integrated Pest Management- A significant program is emerging that will allow pest management alternatives for urban and suburban environments by providing professional turf managers a means to make more-informed decisions concerning control of fungi Rhizoctonia, large patch of zoysia (as a weed) and the weed roughstalk bluegrass. Research will allow turfgrass to be managed more efficiently and with reduced inputs of pesticides. Specifically, our research is providing more efficient strategies for the control of problem pests.

Land Management- Water and air quality concerns including hypoxia and greenhouse gas emissions have focused public concern on agricultural management practices. Current recommendations for nitrogen fertilizer for intensive production agriculture frequently do not result in the application of the optimum rate and excess nitrogen can contaminate waterways. Technologies that sense crop greenness early in the growing season are now widely available. Work at Purdue University is showing a strong potential for such technologies to provide accurate assessment of crop nitrogen need in a wide range of environments, suggesting these technologies will be helpful in making resource-use efficient and environmentally benign nitrogen management decisions.

Under Goal 4, Purdue is continuing to provide the technologies, practices and systems needed to sustain and enhance our natural resources while addressing the productivity of agricultural operations and the development of stronger rural economies.

Successes:

- Have developed conclusive evidence that adding biosolids in a manner consistent with current regulations poses no environmental threat.
- Developed a new method that compares and maps waste-water loading rates with soil morphology and particle size analysis data and correlates this to the actual rate at which soil will disperse water (measured in the field). This provides a better means of sizing and locating onsite waste water treatment systems.
- Developed a method using low crude protein, synthetic amino acids, genetically enhanced corn and phytase in pig diets that can significantly reduce nitrogen and phosphorus excretion, and ammonia emissions while maintaining pig growth, carcass quality and productivity.
- Providing Indiana grain growers with alternative pest management strategies for stored grain.
- Provided Indiana tomato growers with the information they need to choose a weed management system that best suits their needs.

Benefits:

- By using these modified pig diets, pork producers can significantly reduce land requirements for manure application, enhance water quality by reducing the threat of nitrogen and phosphorus pollution, enhance air quality by reducing ammonia emissions and other odorous compounds and sustain profitable pork production compatible with environmental stewardship.

- By carefully managing, the types of flowers and planning in a landscape we can greatly increase local abundance of natural enemies by providing them the proper shelter, and food. In this vain we have document how populations of a beneficial wasp are able to track the population of mimosa webworms and reduce their abundance on street trees. Taken together, our findings provide clear evidence about how actions can be taken to conserve the beneficial insects that reduce the abundance of pests in the landscape without increasing the use of pesticides.
- In the United States more than 15 billion bushels of grain are stored every year. Total annual storage losses assuming a conservative 1% dry matter loss due to insects and fungi is estimated at more than $500 million. Our work is using ozone treatment as an alternative to traditional fumigants is showing it is possible to have pest control and lessen environmental impacts.

State Assessment of Accomplishments:

Research initiatives that fall under this goal are addressing Indiana's priorities for reducing the impact of agriculture on the environment and improving quality of life, while maintaining productivity and promoting economic development. Purdue University faculty are delivering the technologies, tools, and knowledge needed to meet these challenges.

Resources:

Approximately $808,411 Federal formula funds and $6.18 million of state funds plus 61.8 FTEs have been invested in Goal 4. This is a best estimate and these are not presented as auditable numbers.

Key Theme: Wildlife Management (1)

a. *Description:* Avian responses to habitat quality and quantity in Indiana grasslands and wetlands, and continued research on the effects of prescribed burning on the bird communities of oak-hickory forests in Kentucky were studied. One grassland species, the bobolink, occupies farmland pastures and grassland remnants as an interconnected network of small populations. Ecologists call this type of system a meta-population. Grassland birds respond to the continued existence of a network of habitat patches across a region, rather than to the gain or loss of any particular pasture. This suggests that conservation groups and agencies interested in grassland birds must monitor the distribution of grassland habitat across the region, and encourage land-use practices that maintain some pastures and other grasslands throughout Indiana.

b. *Impact:* Work with Bobolinks illustrate how even small patches of grassland habitat can be important for maintaining native bird populations.

c. *Source of Federal Funds:* Hatch and U.S. Forest Service

d. *Scope of Impact:* Indiana

Key Theme: Water Quality, Water Protection (1)

a. *Description:* Pending enforcement of regulations related to nutrient management requires that implementation of a specific management strategy will produce a quantitatively predictable effect on surface water nutrient loading rates. The goal of this project is to enhance our understanding of relationships between resource management strategies, crop productivity and surface water quality. Specific project objectives include characterizing the effect of rotation, nitrogen source, rate and timing of application on crop nitrogen use efficiency, nitroen balance in the soil, carbon sequestration and nitrogen and carbon loss to surface water. This research is on-going at Purdue University's Water Quality Field Station where the soil is a Mollisol, typical of depressional, poorly drained soils of the eastern Corn Belt.

The nitrogen and dissolved organic carbon load to surface water introduced by subsurface tile drains is a function of soluble nitrogen and carbon concentration and drainflow volume. At present, we are characterizing the impact of agricultural management system on crop productivity and mass nitrogen and dissolved organic carbon loss in tile drainage water. Drainflow was monitored continuously in all study years. In most events, average dissolved organic carbon concentrations were greater from plots receiving manure than from plots receiving inorganic fertilizer. Spring flow events had greater dissolved organic carbon concentration than fall flow events. Preliminary analysis of nitrogen source, time of application and rate effects on corn crop productivity revealed that fall application of swine manure did not result in lower yields when compared to a spring application. However, manured plots were lower yielding when compared to treatments receiving inorganic nitrogen fertilizer (comparable rates) suggesting greater loss to surface waters of manure nitrogen when compared to inorganic fertilizer nitrogen. With respect to inorganic fertilizer, when corn was grown without rotation greater preplant nitrogen rates than are currently recommended resulted in significantly greater corn yields in three of seven experimental years.

b. *Impact:* This research is improving our understanding of fertilizer use efficiency and of the active soil carbon/nitrogen pools as influenced by agricultural management thereby improving our ability to manage nitrogen and carbon in agricultural soils. When corn was rotated annually with soybean, corn yields were maximized with current fertilizer recommendations. For both rotated and non-rotated crops in most years, a 10% reduction in recommended rates could be achieved without yield reductions by delaying the timing of application from before planting to the V4 growth stage. Research completed this year provides a multiyear evaluation of current nitrogen recommendation rates and lower, more agronomically efficient rates. Our results show that producers can reduce nitrogen rates by at least 10% and achieve the same yields if they shift the timing of application from before planting to the early vegetative stage. These results are being used to guide farmers on optimizing management and to inform regulatory efforts targeted at surface water and atmospheric impacts of agro-ecosystems.

c. *Source of Federal Funds:* Hatch and USDA-National Research Initiative

d. *Scope of Impact:* Indiana

Key Theme: Natural Resources Management (1)

a. *Description*: Presently, sixty percent of all wastewater treatment biosolids are recycled, compared to 30% in 1990. The promotion of beneficial use of biosolids has transformed our historic view of processed wastewater treatment residuals. Instead of wastes requiring disposal, we now view biosolids as valuable manufactured products. Land application of biosolids has proven to be beneficial because organic matter and nutrients can be used effectively for enhancement of agricultural crop production. There is concern, however, about the potential for degradation of soil quality and human health effects. Although thorough investigations of potential risk from biosolids have generally indicated that land application does not threaten human or ecosystem health, questions continue to arise concerning the safety of biosolids recycling. This project was initiated to evaluate the toxicity resulting from the amendment of soils with biosolids from municipal wastewater treatment. Toxicity was evaluated using standard tests including earthworm mortality, growth, and reproduction; seedling germination and root elongation; microbial respiration; and nematode mortality/reproduction. In addition, chemical lability tests for metals were employed including water soluble, exchangeable, and metals extractable by the physiologically based extraction test (PBET). Twenty municipal wastewater treatment plants were identified to participate in an initial screening of toxicity, and five biosolids were chosen for a more detailed evaluation. In addition, two soils with historically high applications of high-metal biosolids were evaluated. Contaminants examined were Zn, Cu, Ni, Cu, Cr, As, Cd, Pb, and coplanar polychlorinated biphenyls (PCBs). Slight increases in labile metal concentrations for soils receiving long-term applications of 5 years or more were noted. Significant metal concentrations were determined in the soils treated with biosolids containing

higher quantities of metals. Single applications had no impact on metal concentrations. Coplanar PCBs were not detectable in any of the soils or biosolids. Although all target organisms were sensitive to reference toxicants, the bioindicator tests were not able to detect any residual toxicity in amended soils. Some toxicity was observed in a small number of the amended soils, but no clear patterns emerged. Nearly all of the observations could be attributed to routine properties such as slight depression of pH and elevated salinity. None of the metal concentrations were excessive, and most would not be considered elevated. Co-planar PCBs were undetectable. These observations support the notion that current regulations for application of biosolids to soils are providing adequate protection.

b. *Impact:* The results of this research indicate that the use of municipal biosolids in agricultural landscapes should be viewed as a valuable addition. This work on biosolids showed that short-term (single year) applications did not demonstrate a pattern of toxicity to target organisms. Moreover, long-term application of compliant biosolids has not resulted in detrimental effect on soils. Soils with a history of application of non-compliant biosolids (i.e., excessive metal concentrations) did induce some toxicity as determined by some of the ecotoxicity tests. Chemical extractants were selected that were sensitive enough to detect slight increases in metal concentrations in the biosolid-amended soils. Metal concentrations were low, but the sensitivity of the extractants indicates that they can be used to monitor metal accumulation. Therefore, we have concluded that adding biosolids in a manner consistent with current regulations poses no environmental threat.

c. *Source of Federal Funds*: Hatch, U.S. Environmental Protection Agency, and Natural Resources Conservation Service

d. *Scope of Impact:* Multi-state

Key Themes: Biodiversity, Natural Resource Management (1)

a. *Description*: Widespread conversion of deciduous forests to agriculture in the Midwestern United States has resulted in landscapes whose remaining native habitats are highly fragmented, with well-documented consequences for wildlife community structure. Trap data were analyzed for five forest-rodent species from 525 sites in 35 study landscapes throughout the upper Wabash River basin, which is dominated by agricultural use and drains more than 20% of Indiana. A recently developed likelihood approach and multi-model inference was used to obtain unbiased estimates of occurrence probabilities for a species when detection rates are less than one, and a hierarchical generalized linear modeling approach was used to evaluate random effects associated with nested data structure. Inclusion of a spatial autocovariate term had important effects on model selection results for 4 of 5 species and improved fit of models. Eastern chipmunks (*Tamias striatus*), although previously described as sensitive to fragmentation, were nearly ubiquitous in our study region and had greater occupancy rates in smaller woodlots. Fox squirrels (*Sciurus niger*) are well adapted to patchy landscapes, and their occupancy rates actually increased with patch isolation. Gray squirrels (*S. carolinensis*) are adversely affected by forest fragmentation; we observed a threshold decline in occupancy rates beyond ca. 15 km from the Wabash River, which harbors the only source of contiguous habitat within the entire river basin. Red squirrels (*Tamiasciurus hudsonicus*) exhibited greater abundance in sites without gray squirrels. Moreover, their occupancy rates were positively related to habitat and landscapes considered suboptimal (e.g., lower basal area of hard-mast bearing trees, more isolated patches); this was further evidence for negative effects of gray squirrels on red squirrel populations. White-footed mice (*Peromyscus leucopus*) were nearly ubiquitous; although occurrence rates in less forested landscapes increased with distance from edge and greater volume of woody debris.

b. *Impact:* Few studies have examined vertebrate responses to human modification of habitat at multiple spatial scales, and methods for analysis are either unknown or not understood by most professionals. Our

work demonstrates a sampling design and analysis framework for multi-scale studies and documents the importance of examining ecology at multiple spatial scales for forest rodents in Indiana. Our findings point to particularly vulnerable species such as gray squirrels and highlights the areas upon which their survival is most dependent.

c. *Source of Federal Funds*: Hatch and U.S. Forest Service

d. *Scope of Impact:* Multi-state

Key Theme: Integrated Pest Management, Biological Control (1)

a. *Description*: Biological control of aquatic weeds is a new area of work and offers promise as a replacement to use of herbicides or metal-based algaecides. Work at Purdue has concluded on a project to determine the efficacy of using the patented biocontrol agent SG-3 a bacterium, to control blue-green (cyanobacterial) algae. SG-3 was an effective algicide at low cell concentrations on important toxin (*Cylindrospermopsis raciborskii*) and taste-and-odor producing (*Pseudanabaena*) phytoplanktonic blue-greens. SG-3 acted as an algistat on mat-forming species such as Oscillatoria. The SG-3appears to need to be in contact with the cyanobacterial cells in order to cause lysis, however, the slime produced by the mat-formers prevents cell access to the interior of the mat. As part of this project work a real time PCR method is being developed as an inexpensive and rapid detection method for low cell populations of *C. raciborskii*. Primers targeting a region coding for one of the nif genes were found to be specific to *C. raciborskii*. At this time extraction protocols to prepare DNA from lake water are being tested and optimized. In conjunction with this study, water samples collected from Lake Lemon, IN in the Summer of 2005 showed bloom concentrations of *C. raciborskii* as high as 1 million cells/ml. It is clear that a method sensitive to only a few cells/ml is needed in order to initiate control measurements such as the use of SG-3 prior to bloom establishment and the development of resistant mat structures.

b. *Impact:* Our research has helped focus attention on a serious water quality problem, that of the toxic blue-green algae, particularly invasive species such as *Cylindrospermopsis raciborskii*. We are developing a rapid, inexpensive, and sensitive detection method using DNA primers and PCR that could be adopted by water utility and management companies. If cell populations can be detected before they reach bloom proportions, the insertion of a management method could be effective without causing perturbations to the environment (such as toxin release or oxygen depletion). We also now have a body of information on a potential biocontrol agent for *Cylindrospermopsis*, which, if future testing continues to show promise, could substitute for the current copper applications that are currently being made to infested bodies of water.

c. *Source of Federal Funds*: Hatch

d. *Scope of Impact:* Multi-state

Key Theme: Integrated Pest Management, Biological Control (2)

a. *Description*: Strategies for developing novel biological control methods are emerging. We manipulated densities of flowering plants to test the hypothesis that ornamental landscapes with floral resource plants contain more natural enemies than landscapes without these plants. We established an experimental landscape consisting of 3 x 3 m plots that contained a central bed of Euonymus fortunei (Turcz.) and either low or high densities of four species of perennial flowering plants that were planted through wood mulch. Control plots included only mulch. The cultivars of perennials, *Trifolium repens L.*, Euphorbia polychroma L., *Coreopsis verticillata* L. var. Moonbeam, and *Solidago canadensis* L. var. Golden Baby,

were chosen because their staggered bloom periods would provide nectar and pollen for natural enemies throughout the summer months. Total natural enemies, and spiders and parasitic wasps, specifically, were typically most abundant in euonymus beds surrounded by flowering plants. The abundance of parasitic wasps and total natural enemies on sticky cards was positively correlated with biomass of Euphorbia polychroma within plots, and that of all flowering plants combined. Removal of inflorescences from plants in 2003 did not affect patterns of natural enemy abundance or dispersion of natural enemies within the landscape, suggesting that vegetative characteristics of plants, rather than flowers, influenced the abundance of natural enemies.

b. *Impact*: Millions of dollars may be saved by using biological control methods, either individually or in combination with standard agricultural practices. Implementation of biological control in urban landscapes is hampered by lack of information on the effectiveness of natural enemies in the urban matrix. We have found that planting flowers can greatly increase local abundance of natural enemies by providing shelter, and food. Our findings provide clear evidence about how actions can be taken to conserve the beneficial insects that reduce the abundance of pests in the landscape. By demonstrating these effects we hope to convince landscape managers and homeowners about the utility of biological control as an alternative to pesticides.

c. *Source of Federal Funds*: Hatch

d. *Scope of Impact:* Multi-state

Key Theme: Agricultural Waste Management (1)

a. *Description*: The overall objective of this multi-state four-year project was to test, demonstrate and encourage the adoption of new diet modification technologies capable of reducing manure nutrients and air emissions while maintaining high levels of pork production. In addition, models for lean growth to predict nutrient mass balance with different genetic lines and the economic impacts of the new dietary technologies were created and tested. Experiments were conducted with scientists at the University of Missouri and Michigan State University to evaluate the effects of feeding low nutrient excretion diets in both research (1662 pigs) and commercial settings (33,256 pigs) on pig growth performance, carcass characteristics, and nutrient mass balance. We compared a traditional corn-soybean meal based diets to diets formulated with reduced crude protein, amino acid supplementation, and reduced inorganic phosphorus with phytase supplementation, plus low phytic acid corn with soybean hulls and a non-sulfur trace mineral premix. Results of this research showed that these dietary manipulations are effective in reducing total nitrogen, ammonium nitrogen and total phosphorus by 8, 25, and 25%, respectively, in the nursery phase and 21-38%, 25-38%, and 26-54%, respectively, during the overall grow-finish period in research settings. Additionally, aerial ammonia levels were reduced by 59%, 43-60%, and 27-60% in the nursery, grower, and finisher phases, respectively. Aerial hydrogen sulfide levels were reduced by 36% with the feeding of low nutrient excretion diets in one research trial. The feeding of these low nutrient excretion diets maintained overall growth performance and carcass characteristics, however, performance was reduced in some of the trials during the nursery and grower phases especially with gilts. Whole empty body masses and accretion rates of ash, N, and P were reduced with the feeding of the low nutrient excretion diets with minimal effects on bone properties. In commercial conditions, the feeding of these diets reduced aerial ammonia levels by 61%. When the pigs were grown in low health conditions, overall growth performance was reduced. However, when the pigs were grown in high health conditions, growth performance was reduced in the grower phase but maintained during the overall grow-finish phase. Under both health conditions, the feeding of the low nutrient excretion diets maintained carcass characteristics. This research indicated that the feeding of diets formulated to reduce nutrient excretion and ammonia emission is an effective means to reduce the environmental impact of swine production. Due to the reductions in performance during the nursery and grower phase in some trials, it is important to further

investigate the degree at which amino acid supplementation can occur in reduced crude protein without impacting performance. Additionally, there is a need to re-examine the amino acid and phosphorus requirements of today's high lean gain potential genetic lines. Further research is needed to better define the nutrient requirements of high lean gain potential swine, not only in research settings but true commercial settings as well.

b. *Impact:* Indiana's agricultural operations generate some 14 million tons of solid and 1.6 billion gallons of liquid waste annually. These 38,000 production points are increasingly located near urban populations where complaints about odor and water quality impacts are becoming common. Using low crude protein, synthetic amino acids, genetically enhanced corn and phytase in pig diets can significantly reduce nitrogen and phosphorus excretion, and ammonia emissions while maintaining pig growth, carcass quality and productivity. By using these modified pig diets, pork producers can significantly reduce land requirements for manure application, enhance water quality by reducing the threat of nitrogen and phosphorus pollution, enhance air quality by reducing ammonia emissions and other odorous compounds and sustain profitable pork production compatible with environmental stewardship.

c. *Source of Federal Funds*: Hatch and USDA-IFAFS

d. *Scope of Impact:* Multi-state

GOAL 5. ENHANCED ECONOMIC OPPORTUNITIES AND QUALITY OF LIFE FOR AMERICANS

Overview: Purdue University researchers have established information resources that will aid in enhancing the quality of life for the people of Indiana. The recent addition of a Vice-Provost for Engagement and associated support staff has substantially increased Purdue University's role in developing information resources, services, and opportunities to facilitate the development of the state's human capacity, generating employment opportunities, and contributing to economic growth. This is a top priority at Purdue University with direct leadership from the Office of the Provost. The former Dean of Agriculture serves as the Vice-Provost for Engagement with responsibilities to extend all university educational resources to the citizens of Indiana.

A USDA-funded Agricultural Innovations Center composed of Purdue University researchers and county extension staff is helping farmers develop value-added business proposals. Several ethanol plant and biodiesel plants are either under construction or in final planning stages. The New Ventures Team is helping citizens develop business plans for direct marketing, agri-tourism, and community kitchens to help small farmers process produce under sanitary conditions. Educational programs also focus on value-added and niche market opportunities for specialty crop and livestock enterprises. Agricultural economists have developed computer software that helps county government officials determine the fiscal impacts of local commercial, industrial, and residential development.

Successes:

- A case study found intervention techniques to help normal and disabled child interact in more appropriately in a classroom setting.
- An Emotionally Focused Family Therapy Treatment shows promise to reduce recidivism for encarcerated adolescents.
- Recommendations on how to manage conflict resolution in local communities addresses natural resource were developed based on case study interviews.
- Contributions of time, leadership, and money offered by local small businesses can be critical for the success of local community activities.

Benefits:

- A website in Spanish will assist a growing Latino culture with estate planning.
- A multi-state effort developed criteria and educational materials for those who prepare and transport home-delivered meals to older adults that are less prone to foodborne pathogens.
- Survey-based educational materials on entrepreneurial skills should increase the success rate for small businesses in Indiana.
- A fiscal impact spreadsheet model should help local government officials in Indianas 92 counties, 293 school districts, and 560 cities and towns more effectively analyze the economic implications of economic development such as new local industrial, retail, or urban investm**ents.**

State Assessment of Accomplishments:

The many activities under this goal are addressing Indiana's needs in terms of improving the quality of life for the citizens in the state. Purdue University researchers have demonstrated approaches to be used by communities to make better decisions about policies that affect families. Also Purdue University scientists, working with county extension educators and many state and local stakeholders, are providing information on alternatives for debt reduction, tax restructuring, and planning and zoning.

Resources:

Approximately $200,232 Federal formula funds and $797,923 state funds plus 7.2 FTEs have been invested in Goal 5. This is a best estimate and these are not presented as auditable numbers.

5A. Improved Quality of Life

Key Theme: Estate Planning (1)

a. *Description:* Effective delivery of financial education to Latino consumers could help families save wisely, accumulate assets over time, and avoid harmful personal debt. Currently little, if any, financial education in Spanish is available. Funding from an eXtension grant and the Center for Aging and the Life Course at Purdue University, combined with the availability of a native Spanish speaker who is also a financial educator, enabled the development of a prototype website in Spanish.

b. *Impact:* The development of a Spanish language web site,"Planeando un retiro seguro" (Planning for a Secure Retirement) will enable Spanish speaking residents in Indiana to obtain information about retirement-related information in Spanish.

c. *Source of Federal Funding:* Hatch and Smith-Lever

d. *Scope of Impact:* Indiana

Key Theme: Children, Youth, and Families at Risk (1)

a. *Description:* Interviews were conducted with 73 children (32 boys and 41girls, mean age=54 months), who attended inclusive preschool programs to ascertain children's decisions about whether or not to include or exclude a hypothetical child with a physical disability in play activities. Six short vignettes included two types of play activities: interfering (in 3 of 6 vignettes the physical disability interfered play activities, such as kicking a ball) and non-interfering (the physical disability did not interfere, such as playing with puzzles). Four questions were asked: 1) who should get to play if there was only room for one more kid to play? and 2) why did you choose this doll? Then a probe was given to see if the child

would change his/her choice after receiving more information about peers. For example, if the child chose a typically developing doll, the interviewer would ask: what if some kids told you that this kid (in a wheelchair) should get to play because she wants to? Children were more likely to choose the typically developing doll than the doll in a wheelchair, across all vignettes. Children were significantly more likely to choose the doll with the disability when physical disability did not interfere (e.g., looking at books) than when physical disability interfered (e.g., kicking a ball.) In addition, girls were significantly more likely than boys to choose the child with a disability. Children were also significantly more likely to make moral judgments to justify including a child with disability than a typically developing child. Finally, children were significantly more likely to change their choices from typically developing child to child with disability than from child with disability to typically developing child across all contexts. Not only did children use information about disability, their decisions also reflected a sensitivity to the different demands of the play scenarios.

b. *Impact:* This research has important implications for designing interventions to promote social interactions between preschool children with disabilities and their typically developing peers. They suggest that attention to classroom processes, including the demands of the play context, a child's disability, and clear expectations for interaction are likely to increase opportunities for interaction.

c. *Source of Federal Funding:* Hatch

d. *Scope of Impact:* Multi-State

Key Theme: Children, Youth, and Families at Risk (2)

a. *Description:* An evidence-based treatment for couples with incarcerated adolescents has been developed for use with these families to decrease recidivism. In addition, materials for training therapists to use this Emotionally Focused Family Therapy treatment (videotapes and training seminar) have been prepared and therapists have been trained. A preliminary feasibility study comparing the Emotionally Focused Family Therapy treatment to a control group who receive the Multiple-Family Group Intervention is underway. Adolescents and family members in Emotionally Focused Family Therapy receive a total of 9 to 12 weekly, one-hour sessions. Individual family sessions are held at correctional facilities and are conducted by masters level family therapists from the family therapy training program at Auburn University. These therapists have been trained in Emotionally Focused Family Therapy in their practice. All individual family therapy sessions are videotaped. The Multiple-Family Group Intervention control group is a 9-week manualized psycho-educational program. Adolescents and family members in this control group receive a total of 9 weekly, 1.5 hour sessions by similar masters level family therapists. Thus far, 26 adolescents and their families have been treated in a correctional institution. The adolescents are sex offenders between the ages of 14 and 18 and approximately 3 months from release.

b. *Impact:* Many adolescents after release from correctional facilities return to conduct-disordered behaviors. While incarcerated, they attend school and individual and/or group therapy, but their relationships with their families are not often targets for treatment. Therefore, the coercive interactional patterns of these families, which are fraught with conflict and negative affects that disrupt family members attachment bonds do not improve, leaving adolescents disconnected from their families and at risk for re-offending upon release. Adolescents who are attached securely to their caregivers are more successful in negotiating paths to adulthood than are those who are not. Prior to release, re-attachment of incarcerated adolescents with their families and de-escalation of conflict cycles and negative affect might curb conduct-disorder behavior.

c. *Source of Federal Funding:* Hatch

d. Scope of Impact: Multi-State

Key Theme: Aging (1)

a. *Description:* A six state survey (IN, TX, WA, NH, VA, and SC) was conducted to analyze home delivered meal programs. Surveys were distributed in either Spanish or English and multiple contacts were made with the home delivered meal providers that agreed to participate. In summary, 910 consumers, 85 drivers, and 94 managers responded. Consumers were surveyed for general food safety knowledge and handling of meals or leftovers. Drivers were surveyed for handling practices. Managers were surveyed for food preparation, handling, storage, and delivery practices, as well as food safety knowledge. Temperature drop of meals during delivery using computer tags that logged time and temperature were first used to evaluate sample meals in home delivered meal programs, followed by laboratory simulation of meal transport containers. Fourteen transport containers were evaluated, including nylon bags, plastic cooler style containers, electrical units that plugged into cigarette lighters, standard shipping containers, simple corrugated board boxes and plastic bags. Closures included Velcro types, as well as zippers, latches, and simple folded flaps. Analysis included temperature drop of sample meals in unopened containers and when meals were removed every 6 minutes. In addition, three different package types were tested at Clemson University. They included a paperboard tray with food, an aluminum tray with a paper lid, and a Styrofoam container with a flip-top lid. Clemson University also conducted microbiological analysis on sample meals from selected meal preparation sites during different seasons of the year. Instructional brochures were developed using graphics, color printing, and larger size fonts (particularly for the clients) to more effectively present information.

b. Impact: Information provided through this project should improve the safety of home delivered meals and decrease the potential for foodborne illness for older Americans living at home. Approximately 30,000 clients, 10,000 driver, and 600 home delivered meal provider brochures/pamphlets were duplicated for distribution. Brochures are downloadable through the Purdue University Arthur Avery Foodservice Research Laboratory website. Additional brochures were duplicated in Spanish and made available on the Purdue University website to allow for greatest use in various locations throughout the U.S. Foodservice manager guidelines include information on the best containers for keeping hot foods as hot as possible, how transport containers affect food temperatures, how long they have to deliver meals before they become unsafe to eat, and whether they should cook food to higher temperatures so that they are hotter when delivered to clients. Client brochures provide information about how long they may safely leave food unrefrigerated and how best to handle leftovers. Finally, drivers in home delivered meal programs are provided information in their brochure as to how to safely transport meal containers and what to do if there are delays in the deliveries.

c. Source of Federal Funding: Hatch

d. Scope of Impact: Multi-State

Key Theme: Child Care/Dependent Care (1)

a. Description: Seventy-one mother-child pairs from local preschool and daycare organizations in the Greater Lafayette are participating in this study. Initial data analyses indicate that the way mothers organize information regarding child-mother relationships (as assessed through a narrative technique) is significantly related to the quality of care they provide. Importantly, preschoolers mental representations about child-mother interactions are significantly associated with the organization of their behavior during child-mother exchanges. These results are the first to directly tie a specifically proposed information structure concerning child-mother relationships to behavior in both mothers and children. This is central

to understanding the issue of representation of relationships and offers guidelines as to how to address certain issues in parenting intervention programs.

b. *Impact***:** Findings will contribute to our understanding about the development and stability/change in child-mother relationships. More specifically, they will clarify the way knowledge about attachment relationships is organized and represented mentally, and its relationship to the organization of children's behavior. Also, results will contribute to our understanding of the relations between the organization of mothers' knowledge about attachment.. Finally, this work has implications for intervention programs aimed at improving child-parent relationships.

c. *Source of Federal Funding:* Hatch

d. *Scope of Impact:* Multi-State

Goal 5B: Individual, Family and Community Economic Development

Key Theme: Promoting Business Programs (1)

a. *Description:* There is an increased focus on entrepreneurship in Indiana. This study involved 65 respondents, who were surveyed to determine the factors that most affect them as entrepreneurs, given the current demographic status of the entrepreneur and the economic conditions of the area in which he/she resides. Most of respondents were between the ages of 26 and 44, 58% were female, and 78% were white. Only 29% of the respondents had any previous startup experience, but 59% had attempted to write a business plan. Thirty-four percent had a net worth less than $50,000 and 40% had a net worth of over $100,000. Some college education increases an entrepreneur's chances of starting a new business. Attempting to create a business plan increases an entrepreneur's likelihood of starting a new business by 24%.

b. *Impact:* A better understanding of the factors that help or hinder individuals during the entrepreneurial process will provide valuable information to both entrepreneurs and the entities that serve them. The information provided by this study, should help small business and economic development agencies structure their entrepreneurship programs to best meet the needs of their clients; thus, improving the success rate of entrepreneurs.

c. *Source of Federal Funds:* Hatch

d. *Scope of Impact:* United States

Key Theme: Promoting Business Programs (2)

a. *Description:* The focus was on community characteristics, particularly rural/non-rural and socio-economic vulnerability. A community vulnerability scale developed for this project was applied to an analysis of the determinants of family business social responsibility; specifically, four social responsibility factors were identified: owner financial assistance, technical expertise, serving in elected office, and donating to local school and youth programs. About 85% of the family businesses contributed in at least one of these four ways. The education of the owner and the age of the business were significant predictors of the likelihood that the business exercised "social responsibility" in the community. Social responsibility was greater in intensity when the community was rural and vulnerable. It appears that business people recognize a need and attempt to fill it according to their means and the nature of their expertise. Most family businesses find ways to contribute time, financial resources or expertise in their

communities. Because these contributions are valuable assets, it is important that business contributions be measured in some way that would enable communities to determine whether they are adequately tapping the available business resources. Business contributions that are not funneled through a foundation are generally uncounted and unrecognized, yet the majority of businesses are small or medium in size and do not have foundations. It is also key that public policy support, encourage, and reward these contributions so that no policy barriers are placed before businesses willing and able to contribute.

b. *Impact:* Community agencies in rural and vulnerable communities could benefit from resources that family businesses can contribute. Business owners and employees often have the ability to contribute time, expertise and money that may be untapped by community agencies who focus on monetary fund-raising. Understanding of how these resources could be tapped and used will help communities to reduce vulnerability.

c. *Source of Federal Funding:* Hatch

d. *Scope of Impact:* Indiana

Key Theme: Impact of Change on Rural Communities (1)

a. *Description:* The fiscal impact of economic development is the effect of new investment, new construction, new employment, new population, new school enrollment and other changes on a government's budget. If development generates new revenues that exceed new costs, the fiscal impact is said to be positive. If development generates new revenues that fall short of new costs, however, the fiscal impact is negative. The local government must raise taxes to meet new service demands, and (perhaps) reduce the quantity or quality of existing services. A prototype fiscal impact model was developed for use by local decision makers. It includes data on the budgets, appropriations, revenues, tax rates and population characteristics of all 92 counties, 293 school corporations and 560 cities and towns located in Indiana. Model users can identify the local government in which they are interested and the model would select the appropriate government budget and tax data. The user then provides a few details about the local development activities. The model applies fiscal impact methods developed from a review of the literature to the budget and tax data, and the development characteristics.

b. *Impact:* The fiscal impact model for can be used to analysis the budgets of rapidly growing school corporations or school corporations with declining enrollment. It has been used to analyze the effect of riverboat related development on counties, towns and school corporations.

c. *Source of Federal Funding:* Hatch

d. *Scope of Impact:* Indiana

Key Theme: Conflict Management (1)

a. *Description:* An assessment of a collaborative watershed group in Indiana involved qualitative research, primarily interviews and review of documents. To avoid conflicts, participants in collaborative groups need to be clear both with themselves and with other participants who they represent. The study concluded that coordinators of these types of groups need to remain unbiased. The unique aspect of this study is that while they had many difficulties, the interviewees were prepared to discuss them. Most collaborative groups that are studied are “success” stories where everyone is able to put aside their differences and work together towards a common goal. In this instance, participants never reached a common goal.

b. *Impact:* The study helped the group address some of their internal problems. The recommendations should help other community groups function better and result in improved, community-based natural resource management decisions in Indiana.

c. *Source of Federal Funding:* Hatch

d. *Scope of Impact:* Indiana

B. STAKEHOLDER INPUT PROCESS

Engaging stakeholders is a high priority for Purdue University. The Purdue University Strategic Plan approved by the Board of Trustees in November 2001 makes it very clear that engagement with local, state, national, and world audiences is one of the primary missions of everyone at Purdue University. In the Colleges of Agriculture, Consumer and Family Sciences, and Veterinary Medicine, faculty and staff engage stakeholders on a daily basis through activities occurring both within the university setting and across the state and Nation. About one-fourth the faculty in the College of Agriculture have a joint appointment in research and extension. These faculty have extensive interaction with stakeholders through scheduled meetings, on-farm research, problem solving consultations, field days, conferences, etc. Staff participate in a wide variety of state and local events including conferences, commodity marketing associations, and agricultural interest group meetings. Purdue University is reaching new key stakeholders as evidenced by the hundreds of people attending annual horticultural and turf management conferences. In fact, these "green" industry events now attract more participants than the more traditional agronomic field days. Recent events include Extension programs on niche markets and organic farming and educational programs on Asian soybean rust co-sponsored with the Indiana Soybean Board. Several of Purdue University's Centers and Institutes that conduct research have external advisory boards which provide input and guidance on the vision for and needs of various sectors of agriculture, including agribusinesses, food processors, state agricultural organizations, and government agencies. Examples include industry advisory boards for the Department of Food Science and the Crop Diagnostic Center associated with the Departments of Agronomy, Entomology, and Botany and Plant Pathology. The Center for Food and Agricultural Business trains more than 1,000 agribusiness leaders annually with over 100 days of programmed events. Every session is evaluated by the participants.

Another way our faculty and staff remain engaged with stakeholders is through a highly diverse group of organizations that involve producers and citizens with interests in agriculture and natural resources. Purdue University faculty and administrators act as *ex-officio* members or liaisons with 14 of these organizations. These groups are diverse, meet regularly, and are often focused on a particular interest, providing us with an excellent way to interact with a wide cross-section of agriculture interests. The Director and Associate Director of Agricultural Research Programs are both members of the Agricultural Alumni Seed Improvement Association Board of Directors. This facilitates the release of public varieties of wheat, oats, and soybeans as well as germplasm. The Associate Director serves as the liaison with the Indiana Soybean Board and the Indiana Pork Producers Association.

The Department of Foods and Nutrition in the College of Consumer and Family Sciences has frequent meetings with a Corporate Affiliates Advisory Board. The Department of Food Science has an Advisory Board composed of executives in the food processing sector who periodically meet on campus.

The College of Agriculture convenes annual meetings with several different stakeholder groups. These often involve direct solicitations of input from participants. A few examples are described below.

Purdue Council for Agricultural Research, Extension, and Teaching

The Purdue Council for Agricultural Research, Extension, and Teaching (PCARET) organization exists throughout Indiana. Multi-county meetings involve a broad base of stakeholders, plus Purdue University administrators. At the county level, the committee members are identified by current PCARET members, county extension staff and the County Extension Board. County committees elect representatives to the area committee. Area committees elect state leadership. PCARET membership spans a wide range of occupations and interests, including school teachers, livestock and crop farmers, and local business leaders.

PCARET holds regional meetings throughout the state in both the spring and fall. At every meeting, representatives from the College of Agriculture attend to update PCARET members on state and national legislative initiatives and programs. An annual meeting for all PCARET members was hosted on the Purdue University campus in November 2004. Indiana has one of the most active and effective CARET organizations in the United States.

Dean's Advisory Council

The Dean's Advisory Council is made up of representatives from primary and secondary education, producers, farm input industries, banking, agricultural and community associations, the state legislature, environmental organizations, and others. Members are chosen by the Dean with input from the Department Heads. The primary purpose of the Dean's Advisory Council is to provide broad clientele input to the Dean and Associate Deans for Research, Teaching, and Extension. The Dean's Advisory Council meets twice a year. This offers an excellent sounding board for ideas with a wide array of diverse clientele.

College of Agriculture Strategic Plan

Purdue University has developed, and the Board of Trustees has approved, a Strategic Plan for the entire University. The College of Agriculture completed in 2002 a roadmapping activity to lay out a Strategic Plan for reaching "the next level" in learning, discovery, and engagement. Stakeholders from around the state were invited to join administrators and selected faculty at a daylong retreat that kicked off the roadmapping effort. There were subsequent opportunities for feedback from stakeholders as the plan evolved. The College of Agriculture's Strategic Plan has been approved by the Office of the Provost. Each Department in the College of Agriculture has completed a department-level strategic plan which was submitted to the Dean of Agriculture. Individual departments sought input from their various stakeholders as they developed their strategic department plans. This information also is included in the 5-year USDA-CSREES departmental review process.

The Purdue University Strategic Plans calls for hiring 300 additional faculty over five years. The Colleges of Agriculture, Veterinary Medicine, and Consumer and Family Sciences are all benefiting from these new faculty hires. To date about 35 new faculty have been hired in these three Colleges out of an expected allocation of about 45. Priority is being given to three criteria: 1) replacement of Teaching Assistants (TAs) with faculty, 2) cluster hires to focus research and extension expertise on key problem areas where there is a priority need expressed by stakeholders plus funding opportunities, and 3) diversity sensitivity. Last year nearly one-half of the new faculty hires represented women and/or minority hires. This will help Purdue University better reflect the profile of stakeholders that we serve statewide. During 2005, there was substantial progress made in making cluster hires that encouraged cross-campus, interdisciplinary research efforts. This is expected to generate additional extramural research funding and help support the Discovery Park research complex. Several Centers in Discovery Park involve faculty in the College of Agriculture such as bioenergy, nanotechnology, life sciences, entrepreneurship, and environmental sciences.

Indiana Crop Improvement Association

Purdue University has a very close working relationship with the Indiana Crop Improvement Association. Faculty are speakers at their annual meeting and share in program planning. There has been a significant collaborative research effort over the past few years that has resulted in the development of CystX™. CystX™ technology can genetically transform soybeans to be resistant to the cyst nematode, a serious soil pest problem in much of Indiana, and the Midwest, that reduces soybean yields. Some elite soybean varieties were available for planting in 2005, and many more are expected to become available during the next few years. This should help Indiana growers manage the cyst nematode problem and increase soybean yields. Check-off funds through the Indiana Soybean Board have helped finance this effort. This is an excellent example of collaboration among various stakeholders and Purdue University scientists to resolve a major Indiana crop management problem.

Indiana Plant Food and Agricultural Chemical Association

The Indiana Plant Food and Agricultural Chemical Association is composed of individuals from the agricultural input community in Indiana. A typical member sells agricultural chemicals or fertilizers or manages a retail operation. A Purdue University faculty member serves on the board of directors of the Indiana Plant Food and Agricultural Chemical Association in an *ex-offico* status. Meetings of the Indiana Plant Food and Agricultural Chemical Association Board of Directors are held monthly where ideas and issues are discussed. The group also has an active email list and web site where information is exchanged. Individuals from this group also serve on the Advisory Board of the Crop Diagnostic Laboratory which offers educational programs to crop protection professionals.

Indiana State Department of Agriculture

In 2005 the Indiana General Assembly passed legislation to establish for the first time an Indiana State Department of Agriculture. Most state regulatory functions are still located on the West Lafayette campus, e.g., Animal Disease Diagnostic Laboratory and the State Chemist's Office. The Lt. Governor serves as the Secretary of Agriculture and Rural Development. The Director and staff of the newly formed Indiana State Department of Agriculture have developed a Strategic Plan which includes seven initiatives: 1) bioenergy, 2) hardwoods, 3) farm and trade policy, 4) food processing, 5) diversity of production, 6) doubling pork production, and 7) regulatory coordination. Purdue University faculty are engaged in a variety of ways in all of these initiatives. The Dean of Agriculture, Director of Agricultural Research Programs, and other administrators have frequent contact with the Lt. Governor's Office and other state officials. Also Mr. Chuck Connor, Deputy U.S. Secretary of Agriculture, is a Purdue University graduate. He is from Indiana and has frequent contact with Purdue University officials on a variety of agricultural policy topics.

Commodity and Farm Organizations

Purdue University has a close working relationship with various stakeholders through commodity and general farm organizations including the Indiana Soybean Association, Indiana Corn Growers Association, Indiana Pork Producers, Indiana Wine and Grape Council, and the Indiana Farm Bureau. Administrators serve in various *ex-officio* capacities with these organizations. With some, such as the Indiana Farm Bureau, Purdue University faculty and administrators have biennial meetings with the elected Farm Bureau leadership and staff to discuss topics of mutual interest such as agricultural research priorities, state funding support, land use planning, biotechnology, agricultural policy, and local community policy issues. Tours of research facilities are frequently organized for Directors and staff of these organizations.

C. PROGRAM REVIEW PROCESS

The Office of Agricultural Research Programs manages the research portfolios on the principle of one research project per investigator in many cases, but team-based research projects are encouraged and growing in importance. Every Review Panel includes faculty from at least two different disciplines. Research collaboration among faculty across departments, colleges, and universities in other states is strongly encouraged. Project proposals are reviewed as described in the Plan of Work. After rigorous review on campus, nearly 100% of the projects sent to CSREES National Program Leaders have been approved. As in past years, for FY2005 100% of the faculty completed prior to the submission deadline their annual CRIS reports—a total of 350 CRIS reports including NRI grants and multi-state projects.

D. EVALUATION OF SUCCESS OF MULTI AND JOINT ACTIVITIES

Faculty associated with the Office of Agricultural Research Programs at Purdue University are involved in over 100 multi-state projects managed through the four Regional Experiment Station Executive Director offices. These projects have a broad disciplinary base. All these multi-state research projects are relevant to one or more of the five USDA-CSREES goals. The Office of Agricultural Research Programs reimburses the travel expenses of those faculty associated with each approved multi-state research meeting.

Concern about water quality makes it imperative that production agriculture optimize nitrogen use. Concomitantly, interest in using agricultural systems to sequester carbon has highlighted the need to maintain or increase agricultural net primary productivity. A Purdue agronomist has been an active member of NC218, a collaborative research effort among U.S. corn producing states. This project has two objectives common to all participants: (1) the development and evaluation of rapid tests for soil nitrogen mineralization capacity across the various soils and climactic regimes, and (2) the development of the related educational materials on nitrogen best management practices and optimum nitrogen rate determinations for fertilizer management. Previous research has shown that chlorophyll meter readings can reliably indicate nitrogen stress in corn. Chlorophyll meter readings were evaluated to predict corn nitrogen need and yield response well enough to inform management decisions. Sixty-six nitrogen rate experiments were conducted in seven north-central states over a four-year period. Regression was used to relate absolute and relative chlorophyll meter readings to determine an economical nitrogen rate and yield response to nitrogen. Chlorophyll meter readings were significantly related to the economic rate and yield response to nitrogen at all growth stages from V5 to R5. Calibrations were developed to predict economically optimal rates and yield response to nitrogen for growth stages V5 to V9, V10 to R1, and R2 to R5. R2 values ranged from 0.53 to 0.76 for relative chlorophyll meter reading as a predictor of economically optimal rates or yield response to nitrogen. Earlier research has shown that systems with this level of predictive ability produce nitrogen rate recommendations that are more profitable than current nitrogen management practices. Technologies that sense crop greenness early in the growing season are now widely available. The results from this multi-state research effort suggest a strong potential for such technologies to provide accurate assessment of crop nitrogen need in a wide range of environments. This will help growers make resource-use efficient and environmentally benign nitrogen management decisions.

To reduce environmental contamination, it is essential to know the fate of various chemical classes including steroid hormones, antibiotics, pesticides, and industrial chemicals. A Purdue environmental chemist, along with other scientists associated with the multi-state project W82, has studied sorption and aerobic degradation with cobalt-radiated (sterile) and untreated soil-water slurries and moist microcosms of synthetic androgen and three antibiotics common to CAFOs. Microbial degradation of trenbolone led to trendione with limited transformation in sterile soils. Trenbolone half lives across soils are less than 12 hours. Subsequently, trendione degraded with a half life of about four days across soils. Sorption is primarily to soil organic carbon. Half lives for monensin and lasalocid were 2 days and 4.3 days, respectively. Tylosin sorption is dependent on soil clay content and cation exchange capacity with sorption being similar for all forms of tylosin. Degradation in moist soil microcosms with

soil collected from an agricultural field which receives periodic manure application resulted in half lives of 7 - 8 days. Antibiotics and synthetic hormones used in animal production are excreted in the urine and feces, which are commonly land-applied. The members of this multi-state project have concluded that that the androgen trenbolone and the antibiotics tylosin, monension, and lasalocid are highly sorbed to soils or have a relatively short half life in soils. Thus concentrations in nearby water bodies are likely to be small.

In recent years, the soybean aphid, Aphis glycines Matsumura (Homoptera: Aphididae), has become a major pest. A Purdue entomologist has been a key leader in a multi-state research program (S-1010) that has focused on aphid-natural enemy dynamics. Fields have been monitored fields throughout the state of Indiana. There has been a special focus on the dynamics of soybean aphid, its predator, Orius insidiosus, and an alternative prey, soybean trips. Based on a comparison of aphid population growth in the field and in exclusion cages, it was shown that soybean aphid populations were significantly limited by natural enemies. In 60% of cases the aphid populations in the field did not grow while in the exclusion cages they increased in 85% of cases. Moreover, there is a significant negative correlation between aphid population growth and O. insidiosus density, and no correlation with degree-day, temperature and plant complexity. Additionally, the spatial distribution of aphids among plants (clumped and random distributions were tested) seemed to have little impact on the action of O. insidiosus on aphid population growth. Understanding the fundamental mechanisms underlying soybean aphid dynamics will provide pest managers better options to control the pest. The contribution of predators to soybean aphid dynamics is critical to help define the key components of the aphid-predator dynamic in the field.

Both clinical and rat studies are critical to better understand calcium absorption and retention. A Purdue professor in human nutrition and world recognized expert on osteoporosis has participating with other scientists in the a multi-state effort (W1002) that has conducted acute and chronic feeding studies on the effect of purported calcium absorption enhancing components on calcium absorption and retention and bone measures in growing rats. Whey protein and honey and its constituents enhanced calcium absorption in a dose response manner in single meal experiments, but the effect largely disappeared on chronic feeding attributable to adaptation through the calcium homeostatic mechanism. A study in postmenopausal women was completed to determine the effect of various plant isoflavones on calcium absorption and bone resorption. Calcium absorption from milk and calcium-fortified soymilk in young women also was studied. Calcium intake is well below recommended levels for most people above age 9. Whey proteins and honey appeared to be good enhancers of calcium utilization in a single meal, but conferred little benefit in long term feeding. Fortified soymilk was as good a source of calcium as cows' milk.

Purdue University is participating in a multi-state project (NC1003) designed to develop information to be used by public sector research administrators and other groups interested in the acquisition of resources for research, in planning and evaluating research, and in managing public research for the maximum benefits to society. A special publication was generated for administrators as a result of the proposed reduction in and reallocation of Federal formula research funds. This information will assist individual research administrators, regional associations of experiment station directors, legislative aids, OMB, directors of the CGIAR system and administrators of the individual international agricultural research centers, and other organizations in the financing, planning, managing, and evaluating public sector agricultural research. Information generated by the project will be useful to private firms concerned with supplying farm inputs, transportation, storage, and processing of food and agricultural products; and to Congressional committees who appropriate funds and exercise oversight for federally funded research. Special attention has been directed towards management of intellectual property rights by public research institutions, especially as the result of research discoveries in biotechnology.

Soybean rust, now widespread in Brazil, has the potential to become a devastating disease in the United States. Purdue University is an active participant in NC-505, a Rapid Response Research Activity committee. This effort is coordinating the assembly of information among USDA-ARS and land-grant scientists through email exchanges, climatological modeling efforts on air mass movements from the U.S. South to the Midwest that could carry the disease spores, survey design for detection, access to informational websites, research contacts in South America, techniques for potential eradication efforts, and development of educational materials for soybean rust

identification and control including approved fungicides, application procedures, and economic thresholds. Frequent scientific exchanges have occurred on the Asian rust issue among Purdue and Brazilian scientists, several of whom received their doctoral training at Purdue University. Purdue specialists collaborated with the Indiana Soybean Board to develop educational material and conduct meetings state-wide in 2005 prior to the growing seasons on potential control strategies in the event of a soybean rust problem. Fortunately, this did not occur during the 2005 crop year, but farmers, extension educators, and agrichemical firms are now much better prepared in the event that a soybean rust infestation reaches in U.S. soybean production region in the future.

Two Purdue faculty, Drs. Keeney and Ayers, are active members of NC1100. A model using changes in poverty over time within a county (based on the nation-wide U.S. census data) is being refined by the modeling team to identify counties in the United States and North Central Region where poverty growth is significantly above or below the national model prediction for that county. The identification of these areas and analysis of common features that can be attributed to local, state, and federal agency impact across the counties serves as the basis for the writing of a survey instrument that can be used to collect data on individual households in these counties as well as a survey instrument targeted to local officials as respondents. The analysis of the aggregate model and the writing of the survey instruments serve as the basis for a grant proposal that is being written for a National Research Initiative Rural Development project. Purdue has been assigned to the modeling team and will be primarily responsible for focusing on poverty in rural farm-dependent communities using the survey data and the Agricultural Resource Management Survey (ARMS) collected by ERS-USDA assess differential changes in area-wide rural poverty in farming and farm dependent communities and counties. The identification of counties whose poverty growth is much lower relative to that predicted from a model based on the entire country may help identify local strategies of poverty reduction that have been quite successful. The individual data on farmers and non-farmers coupled with farm survey sources offers the potential to assess the role of federal government farm programs on rural poverty.

F. Integrated Research and Extension Activities (Brief Summaries Follow)

U.S. Department of Agriculture

Cooperative State Research, Education, and Extension Service

Supplement to the Annual Report of Accomplishments and Results

Actual Expenditures of Federal Funding for Multistate Extension and Integrated Activities

Fiscal Year: 2005

Select One: □ **Interim** □ **Final**

Institution Purdue University

State: Indiana

	Integrated Activities (Hatch)	Multistate Extension Activities (Smith-Lever)	Integrated Activities (Smith-Lever)
Established Target %	5%	5%	5%
This FY Allocation (from 1088)	4,709,068	8,117,037	8,117,037
This FY Target Amount	$235,453	$405,852	$405,852
Title of Planned Program Activity			
Carbon Sequestration: A Forum on Opportunities in the Eastern Corn Belt		56,403	
Delivery of a Weather-Based Spray Advisory Program to Illinois and Indiana	54,316	54,316	54,316
Emerald Ash Borer Awareness		$23,254	
Improving Quality of Indiana's Apple Crop	47,110	47,110	47,110
Innovation in Handling Large-Scale Animal Mortalities		58,097	
Vegetable Farmers Stay Informed		69,798	
Demand for Certfied Meat Products	36,453	36,453	36,453
Development of Sustainable Biobased Products and Bioenergey in Cooperation with the Midwest Consortium for Sustainable Biobased Products and Bioenergy		60,163	
Sea Grant Academy		20,316	
Multistate Leadership Role - Leadership Development for the 21st Century (LEAD 21)		4,029	
Alfalfa Stand Density: To Keep or Not to Keep - That is the Question	141,620		141,620
Purdue Brings Researchers, Poultry Industry Together to Reduce Pollution	49,138		49,138
Pork Production Systems Modeling	18,952		18,952
New Molecular Marker for CystX will Speed Development of New Soybean Varieties	35,013		35,013
Flowers Lure Good Bugs to Kill Bad Bugs in Landscape	23,254		23,254
Purdue Income Tax School Teaches Tax Professionals about Tax Changes	59,014		59,014
Total	$464,870	$429,939	$464,870
Carryover			

Certification: I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays represented here accurately reflect allowable expenditures of Federal funds only in satisfying AREERA requirements.

_____ **Director** **Date** **23-Mar-06**

Alfalfa Stand Density: To Keep or Not to Keep-That is the Question

There is an ongoing debate concerning how to dense an alfalfa stand needs to be in order to keep it another year. Scientists in Wisconsin suggest that a minimum of 40 shoots per ft^2 is needed for high forage yield. In recent months, they have increased this critical shoot density value to 55 shoots per ft^2. Unfortunately, there is little published data to support their critical shoot values. Alfalfa producers are currently confused by this recommendation because 40 to 55 shoots per ft^2 appear to be a viable stand. Purdue researchers initiated a study in 1997 that continued until 2004 where the response of alfalfa yield and yield components were determined in response to increased potassium and phosphorus fertilizer application. We have 28 yield-shoot density estimates for each of 20 fertility treatments over this seven year time frame. This permits us to thoroughly evaluate the relationship between shoot density and forage yield of alfalfa.

Impact: Under normal fertility management forage yield was not influenced by shoot densities as low as 25 to 30 shoots per ft^2. In exceptional situations when plots were not fertilized, or only potassium or phosphorus were applied (not both), yield declined when shoot densities declined below 40 per ft^2. Under no circumstances were yields increased as shoot densities increased above 40 per ft^2. Our recommendation is that producers consider replacing an alfalfa stand when shoot densities decline to 25 to 30 shoots per ft^2. This critical value is considerably lower than current recommendations (40 to 55 per ft^2), and will give producers the option to keep older stands of alfalfa up to 50%longer if desired without worry of significant loss in productivity. This will spread the high cost of alfalfa establishment ($400/acre) over more production years and reduce costs.

Purdue Brings Researchers, Poultry Industry Together to Reduce Pollution

The broiler industry tends to over-feed protein due in part to lack of sufficient research. This overfeeding creates additional costs for the producer and increased nitrogen emissions from their farms. For years, discussions between academia and amino acid suppliers / academia and formulating nutritionists have occurred on an informal basis, centering around numerous reasons why the industry could not adopt the concept of changing diet formulation from a "total amino acid" basis to a "digestible amino acid basis", including: a) lack of consistent methodologies across labs (academia / contract research facilities), b) need to move forward on filling voids of research - what was and still are limitations from an implementation standpoint, and c) need of establishment of further collaboration/synergy with test tube assays with bird studies. A digestible amino acid workshop/roundtable for the poultry industry was held for academic researchers, all of the U.S. based amino acid suppliers, and formulating industry nutritionists. Representatives from the broiler industry in attendance represented approximately 7 billion broilers or 80 percent of broilers produced in the U.S. each year.

Impact: Purdue researchers helped establish a working group of university and poultry industry staff that will promote reduced-protein feed for broiler producers. The goals of this newly established working group are to fill gaps in knowledge and provide a publicly accessible database of information so that the industry is more able to adopt and advance the digestible amino acid concept. Long-term impacts of reduced protein formulation with adoption of the digestible amino acid concept are greatly reduced feed costs and nitrogen emissions from broiler operations in the U.S. which are imperative with pending ammonia emissions regulations in 2009 and the current water quality regulations for nitrogen pollution.

Pork Production Systems Modeling

Pork producers are striving to produce quality lean pork as efficiently as possible with minimal environmental impact. Feed represents approximately 65% of the costs of pork production. Feeding pigs the optimal levels of essential amino acids and phosphorus will reduce feed costs while reducing environmental impact. Recently a feed additive, Paylean™ has been approved to increase the rate and efficiency of lean growth. The use of Paylean™ must take into account the marketing and production systems. A stochastic version of the pig compositional model has been developed. The model predicts a compositional live weight growth and feed intake

curve for each pig in a 1000 head finisher. The program has been used to: (a) evaluate the optimal marketing strategy with and without Paylean™, (b) the cost of fixed scheduling, (c) the impact of errors in the timing of the initiation of Paylean™ feeding, and (d) the use of new animal sorting technology. The model determines the most profitable series of diets in terms of live weight growth, carcass composition, and feed conversion for Paylean™ - fed pigs for different carcass-value-based marketing systems. The model has been used to establish specifications for a series of diets which maximize profitability for pigs fed Paylean™. Purdue also assisted in the development of a simpler user-friendly version of the computer program which industry technical representatives use to demonstrate the optimal marketing systems to commercial producers. Additional research has evaluate thed use of milk replacers prior to weaning to improve the growth of lightweight pigs and reduce the variation in body weight in the late finishing stages of growth. Research has been initiated to estimate the cost of variation of light weight pigs in late finishing and impact of the marketing system's discounting of light weight pigs.

Impact: Purdue Animal Sciences and Agricultural Economics Departments have developed a stochastic swine growth model that can optimize pork production. This is the first swine compositional growth model that has been developed, parameterized, and tied to a multi-variable decision making program. The program demonstrates that marketing strategies can be improved to increase producer profitability. The feeding of Paylean™ can substantially increase the efficiency of swine growth and profitability. However, the benefits of Paylean™ feeding can only be fully achieved with improved feeding and marketing management. Initial research results indicate that the collection of serial live weight and compositional data as well as development and implementation of the optimal marketing system via animal sorting technology can result in a $7,000 to $10,000 increase in profitability per 1000 head finishing facility.

New Molecular Marker for CystX® Will Speed Development of New Soybean Varieties

Commercial development of high-yielding soybean varieties with CystX® resistance to soybean cyst nematode has been slowed by the complex genetics of CystX® technology. Soybean cyst nematode is a major pest of soybeans, widespread in all soybean producing areas including Indiana. It is best managed by planting resistant soybean varieties. Our soybean cyst nematode resistant germ plasm, known as CystX®, can greatly improve soybean cyst nematode management options. Breeders have been working for several years to incorporate into high-yielding soybean lines our patented germ plasm (CystX®), which provides complete and broad-based resistance to soybean cyst nematodes. Five major companies (including Monsanto) currently have CystX® lines in second-year trials. Commercial deployment of CystX® has been slowed, however, by the complex genetics of the CystX® technology. Recently, researchers at Purdue and Indiana Crop Improvement Association, with partial support from the Indiana Soybean Board, discovered and validated a single nucleotide polymorphism linked to the major locus of soybean cyst nematode resistance in our germ plasm. This SNP is a single change in soybean DNA that recognizes the most important part of the resistance (major locus) when it is present.

Impact: Purdue researchers patented a germplasm for use in soybeans that provides the crops with complete resistance to soybean cyst nematode. Introduction of the CystX® germplasm into commercial soybean lines has been slow to occur because of the complex genetics involved, however. Additional research by Purdue University and the Indiana Crop Improvement Association identified a molecular marker linked to a major resistance locus of CystX® that can be easily detected in resistant lines. The ability to screen new lines quickly with this marker will save breeders time and labor and increase their efficiency. The discovery of this marker and its easy detection are of significant importance to plant breeders and should speed the incorporation of CystX® resistance into soybean varieties suitable for all of the 60,000,000 acres in the U.S. that are infested with soybean cyst nematode. At current soybean market prices this represents more than $300 millions.

Improving Quality of Indiana's Apple Crop

According to a survey conducted in 2005, the codling moth is the most important insect pest that Indiana's apple growers have to manage. For several decades, apple growers have relied on organophosphate insecticides for

managing codling moth and other important insect pests. In 2001 and 2002, there were several reports of control failures with these insecticides. Because resistance had been reported in other states, it was feared that codling moths in Indiana were also developing resistance to these insecticides. One grower reported that he had to discard over 60% of his apples because they were infested with codling moths. He also reported that attempts to use expensive alternative insecticides did not provide adequate levels of control. Insecticide trials were conducted at the farm of the grower who had reported control problems. The organophosphate insecticide Guthion (azinphosmethyl), which had not provided adequate control in recent years, was tested as well as a number of alternative products. The data collected from that study showed that Guthion provided the best control of all products tested, at a level of control that the grower was very pleased with. Several alternative products also provided excellent control. Further investigation found that the grower had been using reduced insecticide rates.

Impact: Through research and extension activities, growers were shown that codling moth could be well controlled on apples using proper rates of common insecticides as well as with several alternative insecticides. Growers were shown that the short term economic benefit of using reduced rates of insecticides can result in very serious long-term economic consequences. Growers were also shown that there are several alternative insecticides that are less toxic that can be used to provide excellent levels of control of codling moth. The grower who previously lost a major portion of his apple crop because of codling moth reported that in 2004 and 2005 he has achieved almost 100% control of codling moth, resulting in fewer culled apples and higher profits.

Flowers Lure Good Bugs to Kill Bad Bugs in Landscape

Implementation of biological control in urban landscapes is hampered by lack of information on how to bring natural enemies into the urban matrix. A Purdue Extension Specialist planted flowering plants in an ornamental landscape to determine how they affect the abundance of beneficial insects. The experimental landscape contained a central bed of winter creeper euonymus and either low or high densities of four species of perennial flowering plants that were planted through wood mulch. Control plots included only mulch. The four perennials we used included white clover, euphorbia, coreopsis, and goldenrod. Insect samples were conducted when flowers were in bloom and when they were experimentally manipulated to remove blooms

Impact: An abundance of parasitic wasps and total natural enemies were found to be positively correlated with the biomass of Euphorbia polychroma within plots, and that of all flowering plants combined. This effect occurred, to a lesser extent, when flowers were removed. Results have been published in the International Journal of Biological Control. These findings provide clear evidence about how actions can be taken to conserve the beneficial insects that reduce the abundance of pests in the landscape. They also provide added motivation for individuals to plant flowers in landscapes.

Delivery of a Weather-Based Spray Advisory Program to Illinois and Indiana

Foliar diseases of muskmelon and watermelon represent potential yield losses for vegetable growers in the Midwest every season. The major foliar diseases of watermelon are anthracnose and gummy stem blight, while Alternaria leaf blight represents the primary threat to muskmelon. At this time, no significant host resistance exists to either of these diseases. While production practices such as crop rotation and fall tillage can mitigate the severity of these diseases, most commercial growers in the Midwest rely on preventive fungicide applications. In a conventional preventative fungicide application program for muskmelon or watermelon, growers rely on a calendar-based application schedule. Most growers apply fungicides on a weekly schedule. Typically, growers transplant into the field in the first week of May. The initial fungicide application occurs by mid-May. Harvest may extend through July for muskmelon and until Labor Day for watermelon. This represents approximately 8 and 14 fungicide applications for muskmelon and watermelon, respectively. The cost of these fungicides represents one of the major expenses to muskmelon and watermelon growers. In an effort to reduce fungicide costs and limit the amount of fungicides in the environment, the MELCAST program was developed at Purdue University. MELCAST is a weather-based spray-advisory program that uses leaf wetness and temperature to

quantify the disease potential for a given time period. Instead of using a calendar-based schedule to apply fungicides to muskmelon or watermelon, commercial growers can now use MELCAST Environmental Favorability Index values as a weather-based threshold. Purdue University recommends a 35 Environmental Favorability Index threshold for the management of both gummy stem blight and anthracnose on watermelon. A 20 Environmental Favorability Index schedule is recommended for management of Alternaria leaf blight on muskmelon. In an average year, the MELCAST program saves the commercial watermelon grower 2 to 3 fungicide applications by indicating when fungicide applications are most critical. During the 2003 and 2004 season, the MELCAST program was used in Illinois, Maryland/Delaware, and Georgia as well as Indiana. The MELCAST system is being tested in Iowa.

Impact: The potential number of fungicides saved can be used to estimate the total impact of this project. In an average year, growers who use MELCAST apply 2 to 3 fewer fungicide applications than if a calendar based system were used. For estimation purposes, let us assume that each one of the 130 growers who received the MELCAST Update saved one fungicide application per season by using MELCAST. This number is probably conservative as many growers saved more than one spray. The total number of acres for the 130 growers is estimated by assuming that each grower has 50 acres of muskmelons and/or watermelons. Some growers have hundreds of acres of cucurbit crops. Therefore, this figure is probably conservative as well. Finally, it is assumed that the ratio of acres sprayed with chlorothalonil to mancozeb were one to one. With this assumption, 6,500 acres for growers using MELCAST in 2003 and 2004 saved approximately $60,303 from reduced application of the two fungicides. The MELCAST system will be delivered to the major muskmelon and watermelon growing regions of Indiana and Illinois so that fewer fungicides are applied over a season. In particular, the amount of carbamate fungicides used by muskmelon and watermelon growers in a season will be reduced.

Purdue Income Tax School Teaches Tax Professionals about Tax Changes

In late 2004, Congress enacted the Working Families Tax Relief Act and the American Jobs Creation Act. These Acts impacted individuals, families and businesses. The child tax credit, marriage tax penalty relief, 10% tax bracket and alternative minimum tax relief were provisions were extended. The American Jobs Creation Act made significant changes in the farm income averaging procedures and created a new deduction for income attributable to domestic production activities. The nearly annual changes in income tax law make compliance with the law difficult for individuals and businesses. Purdue Extension, in cooperation with the Land Grant University Tax Education Foundation, Inc. (LGUTEF Inc.), prepared the 685 page "2004 National Income Tax Workbook" with a 51 page supplement on the American Jobs Creation Act of 2004. Purdue, in cooperation with the Internal Revenue Service and the Indiana Department of Revenue, designed a program using the "National Income Tax Workbook" to update tax professionals on the new law, regulations and procedures. In addition to information enabling taxpayers to comply with the law, educational materials were designed to help individuals understand and evaluate their tax management options. Two-day programs were held in 11 locations in Indiana. In addition, four-hour programs at three locations focused on agricultural tax issues. A two-hour program intended for producers was presented via IP Video. Several shorter presentations were made and supporting publications developed.

Impact: Frequent changes in income tax law and procedures make compliance difficult for individuals, families and small businesses. Purdue Extension, in cooperation with the Internal Revenue Service and the Indiana Department of Revenue taught about 1,100 tax professional about recent changes in income tax law and procedures. These tax professionals estimated that they had prepared over 22,600 Schedule F (farm) and 50,325 Schedule C (non-farm) business tax returns and over 195,000 individual tax returns. The Tax School program was rated as "very good" or "excellent" by 77.8% of the participants and only 2.4% rated the program as less than satisfactory.

Demand for Certified Meat Products

Consumer demand for process verified products appears to be rising, however it is unknown whether consumer willingness to pay exceeds the costs of certifying compliance with process standards. In addition, it is not clear to what extent markets will expand to increase market access for farmers who see dwindling alternatives in the marketplace. Purdue Extension estimated the willingness to pay for natural pork products and determined the potential for market expansion with the introduction of such a certified product. This was done in the context of an assumption of heterogeneity on the part of consumer demand whereas previous theoretical work assumed that all consumers uniformly preferred the certified product. Members of the farm community can find new marketing opportunities in the area of natural pork production if they develop appropriate standards aimed at meeting concerns of consumers and use a third party to verify their compliance with those standards. The analysis was developed into a pilot business plan used by the Agricultural Innovation and Commercialization Center at Purdue as a model for marketing a process as a product attribute.

Impact: The results of the analysis suggest that there is a large segment of consumers (~43%) who have substantial willingness to pay for antibiotic free, environmentally friendly, and animal welfare certified pork. The results suggest that as much as 62% of the market could transition to such a product in the long run. Members of the farm community and groups of farmers are beginning to examine the development of standards for similar products. The details of developing standards and the strategies associated with launching such new products with these groups were discussed.