NORTH CAROLINA
AGRICULTURAL RESEARCH SERVICE

PLAN OF WORK

2000 Annual Report of Accomplishments and Results

North Carolina Agricultural Research Service
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INTRODUCTION AND CERTIFICATION

North Carolina State University is North Carolina's 1862 land-grant university and the only Research I land-grant institution in the state. The North Carolina Agricultural Research Service (NCARS) within the College of Agriculture and Life Sciences serves not only as the college's agricultural, environmental and biological sciences research arm but also provides the research foundation in these areas for educational activities within academics and extension. NCARS is the principal state agency for research in agriculture, life sciences, forestry, and family and consumer sciences. Its research projects involve NC State University's colleges of Agriculture and Life Sciences, Forest Resources, Physical and Mathematical Sciences, Engineering, and Veterinary Medicine and the School of Human Environmental Sciences at the University of North Carolina-Greensboro. Within the college, NCARS coordinates research in 18 departments and works in partnership with the North Carolina Cooperative Extension Service and Academic Programs.

The mission of NCARS is to develop the knowledge and technology needed to:

- improve the productivity, profitability and sustainability of industries in agriculture and life sciences;
- conserve and improve the state's natural resources and environment;
- improve the health, well-being and quality of life of all citizens of North Carolina.

In FY2000, NCARS personnel include 300 research faculty accounting for approximately 160 full-time scientist equivalents, most on shared appointments with academics or extension. Working with these faculty are over 250 graduate students, researchers and research assistants; 450 laboratory and field technicians and 120 clerical staff. These faculty and support personnel conduct basic and applied research in over 550 projects to support more than 70 commodities as well as many related agribusinesses and life science industries.

The following Plan of Work Annual Report highlights accomplishments and impacts of research conducted through the North Carolina Agricultural Research Service and emphasizes the high priority areas in agriculture and life sciences for North Carolina now and in the near future.

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I. PLANNED PROGRAMS

National Goal 1:
An Agricultural System That is Highly Competitive in the Global Economy

Program Area 1:
Technologically Integrated and Sustainable Crop and Livestock Production Systems

Subprogram Area 1a:
Crop Production Systems

Overview

Research activities in this program area have concentrated on development of improved pre- and postharvest handling techniques; production management systems; and acceptability/quality of field, fruit and vegetable crops. In addition improved production management systems for ornamental and floricultural crops, turfgrass, and landscape plants to enhance rural and urban environments. Some highlights of accomplishments in this program area are listed below.

- Biological control strategies for silver whitefly in greenhouse production of tomatoes have been evaluated and demonstrated to be successful.
- Successful protocols for organic production of greenhouse tomatoes have been developed and production was comparable to conventional practices.
- A web site http:www.ces.ncsu.edu/greenhouse_veg/ has been developed to distribute greenhouse vegetable production information in general and biocontrol and organic production in particular.
- Five strategies for transition from conventional to organic farming systems were initiated in 2000 at the Center for Environmental Farming Systems to determine the most feasible and economical method of making this transition.
- Optimal cultural practices for the woodland botanical and highly valued medicinal herb goldenseal have been developed. This is a alternative crop for western NC growers.
- A high speed HPLC assay was developed for identifying the active ingredients(hydrostine and berberine) in goldenseal. This will assist in identifying which cultural practices are most conducive to producing high levels of these ingredients.
- A new soybean variety "Satellite" which has low levels of the undesirable polyunsaturated fatty acid linolenic acid has been developed. This variety produces a cooking and salad oil comparable in quality to canola.
- Acreage of blackberries has increased 20% over the past 5 years as the result of information provided by NCSU personnel in response to the current unlimited demand for this fruit.
- The Specialty Crops Program identified a specialty melon "Sprite" which was successfully commercially produced and marketed in 2000. As the result of this success acreage for 2001 will increase to 38 versus the 2 acres grown in 2000.
- The peanut variety NC 12C released by NCSU was the most commonly grown seed peanut in NC in 2000 with approximately 28% of the total certified peanut seed acreage planted to this variety.
- Studies conducted to determine nitrate leaching on several NC golf courses indicated that the potential for nitrate leaching from properly managed golf turf is not of a magnitude to cause alarm.

- The PourThru Nutritional Monitoring Program to determine the nutritional status of floricultural crops has been developed and refined. This is a fast and convenient method of grower in house testing of pH and EC of growing media.
- An aluminum amphorous mineral, allophane, has been identified as a potential component to include in soilless media, which when charged with phosphorous could supply the entire amount of phosphorous needed to grow a floriculture greenhouse crop thereby eliminating the need for post plant applications of phosphorous which would reduce phosphorous levels in irrigation effluent.
- Successful interspecific hybridization between Buddleia davidii(butterfly bush) and B. lindleyana was accomplished resulting in a unique hybrid with distinct ornamental attributes.
- Rye varieties used as cover crops in sustainable agricultural systems were found to vary in their ability to suppress weeds.
- Progress is being made in utilizing wild peanut species for incorporation of disease and insect resistance in peanuts which will lead to reduced use of fungicides and insecticides in this crop.
- Linkage between molecular markers and genes conferring root knot nematode resistance; southern corn root worm; leafhopper; and several components of early leaf spot resistance have been identified.
- The establishment, production and utilization of native grasses especially switchgrass and gamagrass, are being determined so these species can be more readily utilized to reduce stream and river pollution.
- Reduce tillage systems for peanuts are as successful as conventional tillage on coarse textured soils but are less consistent on fine textured soils.
- Small grain management systems developed to incorporate resistant wheat varieties and seed treatments were utilized in 2000 and helped reduce hessian fly infestation in a cost effective manner.
- High density apple orchard management has been specifically adapted and developed for southeastern environmental conditions which has enabled NC growers to adopt these systems more readily.
- Significant progress has been made in defining selection criteria for heat tolerance in tomatoes.
- The USD/ARS potato selection BO 564-8 yields and chips as well as the variety "Atlantic" the chipping variety of choice in NC. This clone which may be released soon does not suffer from internal heat necrosis, a major defect of Atlantic.
- Release of improved "Beauregard" sweetpotato clones has resulted in a dramatic improvement over the conventional "Beauregard" clone and the improved materials have been widely accepted by growers allowing them to improve productivity and quality.

Key Theme - Diversified/Alternative Agriculture

a. North Carolina farmers need new, competitive agricultural opportunities if they and the rural areas they support are to be economically healthy. The College of Agriculture and Life Sciences at North Carolina State University joined forces with the North Carolina Department of Agriculture and Consumer Services to create the North Carolina Specialty Crops Program. The program is designed to accelerate identification and development of new commodities and value-added products. Researchers determine how best to grow new crops under North Carolina conditions, while a market analysis is done to determine the size and location of a market for a crop. If a crop shows potential in the research field and test markets, extension faculty work with farmers to begin small-scale on-farm production. Marketing of crops from these on-farm trials is coordinated by the program's marketing specialist. If these efforts are successful, a grower education campaign is launched on cultivation and marketing of the crop.

b. Impact - A growers association has been formed through the program and is shipping produce under a Carolina Specialities label. Commercial acreage of seedless red watermelon, leaf lettuce and Sprite melons has been increased as a result of program efforts. Research is being conducted on Oriental melons, high-fructose grape tomatoes, seedless yellow and orange watermelons, pyrethrum (for insecticide production), a super-hot industrial pepper, red kernel sweet corn, vegetable soybeans, Hispanic vegetables, Boniato sweet potatoes, blackberries and off-season greenhouse blueberries and strawberries.

c. Source of Funds - Hatch, State and Smith-Lever

d. Scope of Impact - State

Key Theme - Diversified/Alternative Agriculture

a. During the 1980s the use of medicinal herbs increased dramatically, aided by clinical trials that verified the efficacy of many traditional herbal medicines. Today, the herbal/nutritional supplement market is valued at about $2 billion nationwide and $15 billion worldwide with an annual increase of 15%. The vast majority of medicinal plants are either collected from wild populations, or grown outside the United States. The growth and collection of medicinal herbs is an important contributor to rural incomes in many areas, including Western NC. The demand generated by this market has brought with it the problem of over-harvesting and the loss of native populations. Uncontrolled harvesting in the wild threatens the diversity and even the existence of these native plants. Many small farmers produce herbs for the medicinal and personal care products industries. Significantly, these same growers frequently farm burley tobacco and are justifiably concerned about the future of tobacco production in light of the Tobacco Settlement and recent reductions in quota levels. This has resulted in strong interest in further agricultural diversification. A program has begun that will develop sustainable propagation and production methods for medicinal plant species native to NC. During 2000 we developed a high speed HPLC assay for the active ingredients in goldenseal; began a systematic examination of extraction procedures for goldenseal; began methods development for analysis of black cohosh; and continued to monitor and collect data from field and forested plots of medicinal herbs. Preliminary results indicate that the use of rhizomes differing in size and lateral bud number in a system of sustainable propagation/production of goldenseal results in good stand establishment regardless of treatment. All treatments appeared healthy, with few disease symptoms.

b. Impact - This work supports an existing network of small Western NC farmers who produce medicinal herbs to supplement their incomes. Sustainable production methods will permit these growers and new growers to increase their production while easing the threat to wild populations threatened by harvesting from the wild.

c. Source of Funds - Hatch

d. Scope of Impact - Regional

Key Theme - GIS/GPS

a. Ground- and surface-water nitrogen (N) contamination from southeastern Coastal Plain agriculture is a regulatory and social issues threatening regional crop production. Nitrogen fertility has traditionally been managed on a whole-field basis, which does not take into account soil and crop spatial variability that affects crop N demand and N-use efficiency. Scientists in the Crop Science Department at North

Carolina State University have developed techniques using aerial color-infrared photography to determine optimum timing and rates of N fertilization of winter wheat. Similar techniques are being developed for corn. Scientists in the Department of Soil Science are assessing other remote sensing techniques to characterize the spatial variability of soil characteristics which affect crop production and N-use efficiency.

b. Impact - Tailoring site-specific N fertilization of row crops to spatially variable crop status, soil properties, and projections of potential yield has the potential to optimize N-use efficiency and improve crop yield and quality. This spells greater profitability for producers. At the same time, optimizing N-use efficiency will minimize the amount of excess N that can pollute ground and surface waters.

c. Sources of Funds - Hatch, State

d. Scope of Impact - Regional

Key Theme - Innovative Farming Techniques

a. Making weed management decisions that are environmentally and economically sound is a complex task. Most fields in the South are infested with many different weed species, which vary in their ability to cause crop losses and harvest difficulties. Weed populations that are left uncontrolled can result in near total crop losses. Consequently, herbicides are used on over 96 percent of corn, soybean, peanut and cotton acreage in the South, according to the National Agricultural Statistics Service. Nationally, herbicides accounted for 90 percent of all pesticides applied in 1996 to soybeans, corn and cotton. From both an economic and environmental perspective, it is essential that herbicides only be applied when their use is clearly justified. And in cases where a herbicide is necessary, selection of the appropriate chemical and rate for the mixture of weeds in the field is critical. Use of an inappropriate herbicide or the wrong rate may be ineffective, leading to additional treatments to correct the initial mistake, or result in yield losses or chemicals being released into the environment unnecessarily.

. Scientists at North Carolina State University have developed a computerized weed management decision aid, named HADSS, to assist extension personnel, consultants and growers in evaluating the situation in each field and determining if a herbicide application is necessary, and if so, the appropriate chemical and rate to apply. HADSS allows users to compare different weed control methods and evaluate the potential benefits of shifting to crop cultivars or hybrids that have been genetically engineered for tolerance to specific herbicides. It also maintains a field history of herbicide applications, so that the program can warn users if overuse of herbicides with a particular mode of action may increase the risk of developing a weed population that is resistant to that chemical. It provides a direct link to current herbicide label information over the World Wide Web. In the future, it will import and export field information from a program named Pocket HERB that has been developed to run on the new Windows CE palmtop computers. These programs are based on many years of field experience by weed scientists in North Carolina and across the South. Thanks to funding from USDA, researchers at North Carolina State University are currently cooperating with weed scientists across the South to develop versions of HADSS that have been customized to fit conditions and management practices in each state. HADSS has been field tested in North Carolina, South Carolina, Georgia, Alabama, Louisiana, Mississippi, Tennessee, Arkansas, Oklahoma and Texas. These trials gave a clear indication that HADSS can duplicate the expertise of university weed scientists in most situations. HADSS is currently available for North Carolina (corn,

soybean, peanut), Georgia (soybean and peanut), and Mississippi (soybean). As additional field validations are complete, HADSS will be available to extension agents, growers, consultants and other decision makers across the South.

b. Impact - With millions of acres of corn, cotton, soybeans and peanuts planted in the South each year, the potential impact of HADSS is enormous. HADSS captures the expertise of weed scientists across the South, organizes their knowledge into an easily usable format, and provides a framework for making results of research on new products quickly available to decision makers. At a time when resources are stretched to the limit, the programs can help extension specialists and agents do their jobs more effectively. The use of HADSS will support and encourage making herbicide decisions based on field- and site-specific conditions and applying appropriate levels and types of herbicides. Potentially, the program can reduce herbicide applications and improve the economic status of growers across the South.
c. Source of Funds - Hatch, State

d. Scope of Impact - Regional

Key Theme - Organic Agriculture

a. The Center for Environmental Farming Systems (CEFS) is dedicated to developing farming systems that are environmentally, economically, and socially sustainable. Established in 1994 near Goldsboro, NC, the Center has over 2,000 acres (1,000 cleared). This unique Center is a partnership among NCSU, NC Agriculture and Technical State University, NC Department of Agriculture and Consumer Services, non-governmental organizations, and other state and federal agencies, farmers and citizens. Citizens of NC and other states are currently faced with landscape-scale issues like ground and surface water contamination, soil erosion, declining soil quality, loss of wildlife habitat, and declining rural communities. Only long-term, large-scale interdisciplinary systems research can adequately address these issues. Interdisciplinary research is being aimed at developing profitable agricultural systems that also protect our environment and enhance our rural communities.

. Two major research efforts have been initiated at CEFS. The first is a long-term experiment comparing five very diverse agricultural systems including a best management practice system, organic system, integrated animal/crop system, forest wood-lot system, and a successional ecosystem. Systems will be compared on many integrating factors including energy and nutrient flows within the plant-soil system, biological-based shifts, and economic performance evaluations. Data collection will cover the broad range of factors critical in agricultural systems, and will facilitate the study of large scale issues like impacts on farmers and communities. Many faculty and graduate students are involved in this interdisciplinary effort.

. The second experiment is to investigate various strategies, from a biological and economic systems perspective, for making the transition from a conventional to an organic agricultural production system. This experiment will take place within the context of the larger systems experiment described above. It has been documented that when growers transition from conventional to organic production systems, there is a period of suppressed yields followed by a return to yields near or equal to conventional production. This transition effect has been attributed in part to time required for necessary changes in chemical, physical, and biological properties of soil which enhance nutrient cycling, plant growth and development, and the biological pest control properties of the system. Six treatments, representing various strategies for transition and appropriate controls, will be monitored for energy and nutrient flows within the plant-soil

system, soil quality indices including a range of soil physical, chemical, and microbiological properties, micro and macro fauna, weed, disease, and insect dynamics, overall productivity, and economic performance.

b. Impact - Long-term and transitional studies on organic systems will provide critical information related to biological, agricultural, economic and sociological aspects of organic production under NC conditions. Also, information on specific cultural practices may be applicable to other low-input, sustainable agricultural systems.

c. Sources of Funds - Hatch, Smith-Lever, NRI, State

d. Scope of Impact - State

Key Theme - Ornamental/Green Agriculture

a. Nursery/floriculture crops have been the fastest growing agricultural sector in NC over the last fifteen years. The wholesale value of these crops exceeded $973 million in 1999 - surpassing tobacco as the number one crop commodity. In addition to economic impact, these crops play a vital role in enhancing and protecting our environment as natural areas continue to be lost to expanding development and urbanization. Research is continuing to develop improved crops with greater adaptability, pest resistance, and commercial potential to improve the competitiveness and profitability of this industry and improve environmental quality of our planet. Application of pesticides on landscape plants can be complicated due to the proximity to people, adherence to reentry restrictions, and concerns about the environment. As such, there is a need for new approaches to pest control in the landscape. An important component of integrated pest management is the development and use of plants with greater natural resistance to insect pests and the development of new pesticides with minimal environmental impacts. Plants for these areas also need to be adaptable to extreme environmental stresses including high temperatures, drought, and periodic inundation.

. This research has addressed diverse aspects of physiology, production, and improvement of nursery crops. Accomplishments have included the identification of superior germplasm, development of more efficient production techniques, and improved understanding g of physiological and biochemical mechanisms involved in greater tolerance to environmental stresses and resistance to problematic diseases and insects. This information has provided a basis for continuing work on developing improved hybrids with greater adaptability, tolerance to environmental stresses, and improved aesthetics.

b. Impact - Identification and development of superior plants and germplasm with greater adaptability and pest resistance will potentially result in reduced need for pesticides, improved environmental quality, greater plant growth and survival, and ultimately greater value for both producers and consumers. For example, white-barked birch trees with resistance to bronze birch borer could have national sales of 2-4 million dollars annually, would reduce the need for pesticides and decrease production costs, and would provide superior trees for more sustainable landscapes.

c. Source of Funds - Hatch and State

d. Scope of Impact - National

Key Theme - Plant Production Efficiency

a. Studies have examined ultra-narrow-row cotton (UNRC) as a possible fit in North Carolina. The system that has been assessed, entails growing plants in rows that are 10 inches or less apart, for physiological, entomological, and productivity characteristics. In many areas of the state UNRC out performs wide row cotton (30 -40 inches) in fiber yielding ability. Also, an earlier ground coverage occurs by the UNRC than conventional row widths, which translates into greater light capture by the plants. This earlier canopy coverage results in a greater rate of photosynthesis (production of sugars) per unit ground area due to greater light capture by the cotton plants. The greater and earlier groung coverage also indicates that UNRC will be more competitive with weeds, because it can more quickly shade the ground and provides a poorer growth environment for the weeds than found in more widely spaced plant stands. Insect damage does not appear to be greatly different between the two production practices.

b. Impact - The cotton growers of the state need solid, unbiased information concerning UNRC and it's potential in NC environments. Much of the early information available concerning UNRC was industry driven and, as a result, could be biased. Current information is valuable to growers who are contemplating a switch from wide row to UNRC. The cost to the grower would be unacceptable if the UNRC system did not perform as expected, since the equipment needs are different for the two management systems. As it stands, UNRC looks promising for some NC regions. It has lower start-up investment and lower overall production costs. The type of harvester used for UNRC is less expensive than the spindle picker used for wide-row production. However, if a grower has a good spindle picker that is paid for, it may not be a good choice to change. One potential draw-back of UNRC is the lower fiber quality due to bark and leaf matter collected with the fiber during harvesting. The result is a lower price per pound of fiber. This problem should be considered prior to any major switch in production practices.

c. Source of Funds - Hatch, State

d. Scope of Impact - Regional

Key Theme - Precision Agriculture

a. Crops in NC are generally produced on fields that have a high degree of variability in soils (both their chemical and physical properties), topography, soil moisture, residual soil nutrients and crop residues. Precision agriculture technology can enable management of fields to account for this variability by using variable-rate control of inputs in order to optimize yields and profits and reduce environmental impacts. Technology developed has advanced rapidly, but implementation and assessment of environmental and economic impacts are not keeping pace. Precision agriculture technologies have been developed for crop production, are gaining acceptance, and are emerging as valuable tools for field management of inputs to help achieve yield potentials. Yield monitors for small grains and cotton have been developed and are being used by producers to record yields. Variable-rate control technology for chemical and seed inputs has been developed, but has not been widely utilized in NC. Soil mapping of soil, ph and nutrients are being generated from grid soil sampling, but need to use smart sampling based on variability.

b. Impact - Producers of corn and cotton in NC can improve efficiency of inputs, reach yield potential and reduce environmental impacts by using precision agriculture technology and management. Cotton yield monitors have been shown to be 95+%, and corn yield monitors 97%, accurate when averaged over a field. With current yield potential and soil maps, producers can effectively manage field variability and

have efficient production. Economic and environmental impacts can be assessed through further research.

c. Source of Funds - Hatch, State

d. Scope of Impact - State

Key Theme - Apiculture

a. Introduced pests, pesticides, and various diseases have significantly reduced the number of honey bee colonies in North Carolina and across the United States. Approximately one third of the managed honey bee colonies and more than 90 percent of feral colonies across the country have been killed in the last 12 years. This reduction in honey bee numbers has significant impact on the availability of insects to pollinate crops that make up as much as a third of the typical American diet. The loss of bee colonies has reduced potential income to beekeepers (based on sales of honey and charges for bee pollination of crops) and increased the cost of managing honey bee colonies due to the increased need for in-hive use of pesticides and medications to control bee pests and diseases. Significant progress has been made in understanding the biology and control of bee pests. Management procedures have been developed in the College of Agriculture and Life Sciences at North Carolina State University that at least stabilize existing honey bee populations and prevent additional permanent losses. At the same time, research clearly demonstrates that a device called a "pollen trap" can be used by beekeepers to reduce significantly non-target pesticide kill of honey bees that are located near apple orchards in North Carolina.

b. Impact - The use of pollen traps near North Carolina apple orchards is expected to save approximately 100 bee colonies and reduce damage to another 500 colonies annually. The value of this reduction in bee kill in increased honey production and reduced management cost should be at least $100,000 per year. The value of bee management procedures designed to protect bees from pests is as yet undetermined; however, there will be an economic benefit from these measures as well as an increase in optimism among beekeepers as the recent downward trend in bee numbers is reversed.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$830,623	$10,826,383	$1,188,248	$1,046,635	22.6	35.8	128.4	33.2

Subprogram Area 1b:
Animal Production Systems

Overview

Research was conducted to improve animal productive efficiency in an environmentally sustainable manner by investigating basic physiological processes of animals, studying relationships among grazing animals, forages,

and the environment, determining the efficiency and profitability of animal production systems, and examining the impact of animal production systems on animal products used by humans and on consumer acceptance of animal products. Some highlights of accomplishments in this program area are listed below.

- Research in the application of biotechnology in beef cattle documented changes in the expression of genes that control fetal growth, resulting in the large offspring syndrome (LOS) in bovine embryos fertilized and cultured in vitro. Control of the expression of these genes holds promise to enhance the adoption of assisted reproductive technologies in the beef cattle industry.
- The microbial population in the rumen of ruminant animals and the products they produce were altered by controlling biomass inputs during in vivo experiments for the purpose of maximizing nutrient use by the animal and minimizing nutrient excretion and waste in the form of ammonia and methane.
- Dairy heifer mortality rates were cut in half in research that investigated relationships among nutritional levels, growth rates and body size. The results documented that appropriate nutritional regimes reduced mortality rates and resulted in heifers being incorporated into the milking herd at an earlier age.
- Reduction in the excretion of nitrogen in the form of urinary urea can be achieved in growing cattle with growth-promoting implants if the rations fed to these cattle are calculated and balanced using metabolic protein rather than crude protein requirements without compromising weight gains or fat-to-lean gain ratios.
- Research using pigs has demonstrated that feeding degermed, dehulled corn can substantially reduce manure production without negative effects on animal performance by increasing the digestibility of corn while decreasing the high-fiber components of corn that is part of the diet.
- Long-term studies in pigs has demonstrated that excretion of zinc and copper in swine waste can be reduced by 30 to 50% as a result of reducing trace mineral supplementation without a detrimental impact of the growth and health of the pigs.
- Alternative animal houses that separate urine and feces in a continuous mode resulting in a dry fecal stream reduced ammonia and odor emissions.

Key Theme - Animal Production Efficiency

a. The US swine industry (including NC producers) have adopted production practices on a large scale which involve early-weaning of piglets. The younger and lighter piglets in this scheme exhibit reduced survival rates and slowed growth. Among the many stressors impacting these pigs is the abrupt switch from liquid feed (mother's milk) to dry feed. Test feeding systems have been developed which supply feed to the newly-weaned pigs in liquid form (i.e., manufactured liquid diets). These systems are designed for ease of operation and cleaning so they may be easily adopted on a large commercial scale.

b. Impact - Superior growth performance has been documented of piglets reared in this system. Indeed, pigs reared with this new technology grow even faster than sow-fed siblings. Recently it has been documented that the improved growth is maintained to market weight and it is anticipated that significant economic returns may be achieved when this system is employed, provided diet ingredient costs are managed properly.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Grazing

a. To support the emerging NC meat goat industry, work began on the evaluation of forages and fodder trees suitable for meat goats and adapted to our environmental conditions and on the use of locally-available byproduct feeds for goats fed forage-based diets. Additional research is exploring non-pharmaceutical approaches to treating goats against gastrointestinal parasites. In cooperation with the NCDA marketing specialist, graded goat sales have been implemented in certain areas of the state to supplement weekly auction market sales, and meat goat shows are now an integral part of the NC State Fair in Raleigh and the Mountain State Fair in Asheville. In addition, educational programs targeting CES agents, commodity associations and other agricultural professionals have been implemented with the objective that meat goat producers will select, adopt and successfully implement best management practices that will achieve business, individual, and family goals related to profitability and quality of life.

b. Impact - Producers in NC sold about 180,000 goats for meat in 2000, generating receipts of over 7.5 million dollars. In addition, the NC meat goat industry breeding stock inventory totals about 122,000 animals located in 3,000 farms, representing a capital of over 12 million dollars. It is anticipated that the meat goat inventory will grow by 8-10% in 2000. The number of sheep and goat producers reporting increased awareness and knowledge of best management production practices were 1479 in 1999, and 1625 in 1998. These figures represent over a third of the number of NC meat goats producers, estimated at 3,000. In addition, the number of sheep and goat producers adopting practices that optimized income were 565 in 1999 and 725 in 1998. These adopted practices and procedures resulted in a total economic impact of $239,750 in 1998 and $198,234 in 1999.

c. Sources of Funds - Hatch, State

d. Scope of Impact - State

Key Theme - Aquaculture

a. Commercial culture of flounder, widely and profitably practiced in Europe and Japan, has not yet been attempted in the United States. Southern flounder has great promise for aquaculture, with a high market value and unique ability to grow well in fresh water. Wholesale prices for fresh flounder range from $5-$10 per pound so the economic potential for cultured flounder is promising. Because their range of distribution extends from North Carolina along the Atlantic and Gulf coast into Mexico, the potential for culture in a large geographic area exists. The goal is to establish practical culture methods and to define nutritionally balanced diets for the mass-rearing of weaned fingerlings and the commercial-scale production of fish. Successful production of commercial-scale quantities of weaned fingerlings has been achieved. Research has defined the dietary protein requirements for juvenile Southern and summer flounder as well as the fatty acid requirements of larvae. These accomplishments are fundamental steps in the development of nutritionally complete diets that will maximize the economic viability of flounder farming. Growth studies of fish cultured at different salinities show that Southern flounder can be raised in fresh water beginning at a very early age without affecting their survival or growth rate.

b. Impact - The establishment of Southern flounder as a new, high-value aquaculture species represents the first introduction of a fish with a worldwide market appeal and the capability of being cultured over a large geographic area. The potential for flounder culture is equal or superior to that of the hybrid striped bass

industry, which has enjoyed a growth rate of 20 percent per year for the past 10 years and the achievement of annual value of more than $3.5 million to North Carolina alone. The economic potential of flounder farming in the United States could reach five-to-10 times the value of the hybrid striped bass industry within the next 10 years.

c. Sources of Funds - Hatch, State

d. Scope of Impact - Regional

Key Theme - Aquaculture

a. Aquaculture is the most rapidly expanding type of livestock farming in the United States and hybrid striped bass (HSB) farming is among the fastest growing forms of finfish aquaculture. Previously, all hybrid striped bass were produced from wild broodfish caught during their spawning migrations. This dependency on wild fish creates numerous problems for the fish farmers and precludes selective breeding of an improved cultivar. If hybrid striped bass farming is ever to reach a level of development comparable to the "broiler' chicken industry, it will be necessary to fully domesticate the parental lines, genetically improve the fish to produce a superior cultivar, and discover breeding techniques that allow them to be reproduced on demand. Selective breeding of striped bass and white bass for HSB has begun. Breeding has shown, for the first time, that the domesticated fish can be used to produce HSB with fecundity, fertility, and yields of fry and fingerlings at commercial scale and rates equivalent to those obtained using fully mature, wild female broodfish captured on or near their spawning grounds. This development removes uncertainty about the viability of the domesticated basses as aquaculture broodstock, opening the door to selective breeding of HSB. The largest and most diverse broodstocks of striped bass in the country have been developed and white bass domesticated over four generations and striped bass over three generations. All striped bass and white bass have been genotyped at three microsatellite DNA marker (MDM) loci in anticipation of developing the first genetic map for these species. Experiments are planned that will identify quantitative trait loci (QTL) based on the DNA markers that can form the basis for a rational selective breeding program. In essence, the presence of MDMs detected by DNA fingerprinting of the fish will be used to predict performance of their offspring in culture. Performance will be assessed as quantitative traits, such as growth rate of feed conversion efficiency. Genotyping of the fish at several more loci will be completed shortly, which will increase flexibility in choosing individual fish to make selected crosses. With Kent SeaTech in San Diego, the largest producer of HSB in the country, a novel procedure for producing highly enriched microsatellite DNA libraries for striped bass has been developed and executed, which will generate several hundred MDM gene sequences in a matter of weeks. The libraries will allow building of the first medium-density genetic linkage map of the bass genome and highly accelerate selective breeding. As the only laboratory worldwide operating at this level of selective breeding of any temperate basses, the top seven producers of HSB in the USA have joined with us to genetically improve HSB for commercial fish farming.

b. Impact - Domestication of the fish, as has been accomplished for both striped and white bass over several generations, opens the door to selective breeding and production of genetically improved HSB for growout. Superior performing fish are needed because the HSB industry faces severe competition from foreign producers of similar white-fleshed fish, either wild-caught or farmed. Improved efficiency of production, via genetic improvements to the fish, will ensure continued competitiveness of HSB farming in the USA. Currently, because they are relatively expensive to produce, HSB are sold mainly to high-end ‘white

tablecloth' restaurants or sold live into lucrative Asian ethnic markets. These markets are limited, creating competition among growers and driving prices and profits down. HSB sales need to expand into the general retail market , which will only be possible if production efficiency can increase, allowing prices to drop while maintaining profit margins. Development of an improved cultivar through selective breeding is key to realize this goal.

c. Sources of Funds - Hatch, State

d. Scope of Impact - Regional

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$481,758	$3,752,393	$511,321	$531,172	14.3	24.7	37.2	10.2

Subprogram Area 1c:
Biological Systems

Overview

Research was conducted to map, identify and analyze genes responsible for quantitative traits; characterize the structure and expression of genes and pathways required for growth, development and behavior; develop new approaches for gene transfer and gene regulation, and new methods for visualizing gene products within cells; identify biochemical factors and pathways involved in response to abiotic and biotic stresses and environmental factors such as drought, gravity, light and pathogens; and elucidate the structure, function and evolution of macromolecules that are key to growth, development, defense and behavior. Some highlights of accomplishments in this program area are listed below.

- The nature of genetic variation for *Drosophila* longevity in a population of recombinant inbred lines was investigated by estimating quantitative genetic parameters and mapping quantitative trail loci (QTL) for adult life span in five environments. There was highly significant genetic variation for life span within each sex and environment. Map positions and effects of QTL affecting life span were estimated by linkage to highly polymorphic transposable element markers. A minimum of 17 QTL were detected; all were sex and/or environment-specific.
- Quantitative trait locus (QTL) mapping was used to evaluate the genetic basis of variation in eight *Arabidopsis* floral characters in the Landsberg erecta X Columbia recombinant inbred line population. A composite interval mapping analysis detected 18 significant QTL affecting at least one floral character. Eleven QTL ere associated with several floral traits, supporting either pleiotropy or tight linkage to major determinants of floral morphological integration.
- A novel signal transduction pathway in plants was elucidated through studies on the protein kinase SK1 in soybeans. Discovery of this pathway has yielded new insights into how plants recognize osmotic stresses, such as high salinity and drought, and adapt to survive under conditions of water stress.
- A geminivirus silencing vector for *Nicotiana benthamiana* was developed and used to demonstrate the silencing of an endogenous gene encoding a DNA replication protein in plant meristems. Silencing

the gene stopped all primary growth and produced meristems that lacked primordial, suggesting that there are two-way interactions between development and the cell cycle.

- Advances in light microscopic methods were made through the development of Polarization Modulation Differential Interference Contrast Microscopy which allows better contrast and resolution when imaging living cells, and through modification of spinning disk confocal microscopy. These methods will allow single molecules to be imaged at high resolution in cells and are expected to be increasingly important for genomic and proteomic studies.
- *Arabidopsis* plants transgenic for a heat shock-inducible calcium-binding peptide targeted to the endoplasmic reticulum were constructed. Induced plants accumulated higher levels of calcium, and this calcium reserve can be used to help the plant during low calcium availability.
- Some early biochemical events during graviperception in maize have been identified. The phosphoinositide signal transduction pathway was shown to be part of the mechanism by which cells perceive a positional change relative to the gravity vector.
- Incubation temperatures and eggshell conductance were used to lengthen or shorten incubation periods of turkey embryos. Delaying embryonic development approximately one day resulted in a significant three-way interaction among incubation temperature, egg weight and eggshell conductance. These studies will assist turkey hatchery managers in matching incubation conditions to egg weight, eggshell conductance and the length of the incubation period, management factors that may improve hatchling survival and growth.
- A number of candidates genes that contribute to odor-guided behavior in *Drosophila* were identified. The candidate genes include a novel odorant binding protein, an odorant receptor, a putative kinase and a protein that may be important for synaptic integrity in the chemosensory pathway.
- Incubation conditions that could cause cardiac damage and lead to chick mortality were tested. Incubation temperature and eggshell conductance were shown to be factors causing heart damage as determined by blood TroponinT concentrations and verified by lactate dehydrogenase and creatine kinase activities.
- Studies of enzymes in the phosphatidylcholine (PC) biosynthetic pathway in soybean demonstrated that PC biosynthesis in plants is fundamentally different than that observed in animal and yeast systems. These studies are important because PC is not only a critical structural component of cellular membranes, but is also an important intermediate in triacylglycerol biosynthesis and additionally serves as a reservoir for important signaling molecules.
- Two regionally-expressed, partially redundant genes encoding cofactors that interact with the Deformed homeoprotein in *Drosophila* to specify body pattern during embryogenesis were identified. That these proteins are encoded by redundant genes may explain why such cofactors have been difficult to identify through traditional genetic methods.

Key Theme - Biobased Products

a. Numerous papilloma viruses cause severe disease in both animals and humans. Of special note, two of these which attack humans produce not only troublesome papilloma lesions, but are also the direct cause of important cancers. One of these causes cervical cancer, the single greatest cause of cancer-related deaths in women worldwide. The other resides in the pores of the skin, and when activated by sunlight, causes the development of a certain type of common and quite serious skin cancer. Both of these diseases could be prevented by immunization against these viruses. Such a vaccine has been developed, but currently available technologies for production of the vaccines are prohibitively expensive. Thus the vaccines cannot be introduced into human clinical trials, and their deployment seems in doubt. A more

cost-effective production system is desperately needed if these vaccines are to reach the at-risk populations. Genes encoding the L1 capsid protein, which serves as the immunogenic agent, have been introduced into tobacco, so that the vaccine can be made by the tobacco. Tobacco produces more biomass per acre than virtually any other crop currently grown, making it an ideal "factory" crop. A system is being developed which would allow the simultaneous extraction of the vaccine and a wide array of other valuable products from the transgenic tobacco. Using this system, the costs of production and purification of the vaccine would be offset by the combined value of all of these products. These tobaccos will be grown in the field in the summer of 2000, and vaccine and other products will be extracted to determine the amount of vaccine that could be recovered, and to estimate its cost.

b. Impact - A system has been developed which could allow the cost-effective production of important vaccines which could protect against certain papilloma viruses. Importantly, this system could be used to produce many other native and transgenic products from genetically modified tobacco. This could lead to the development of a new industry for North Carolina which could help to offset losses in revenues from tobacco grown for traditional uses.

c. Sources of Funds - Hatch, State and NRI

d. Scope of Impact - National

Key Theme - Biotechnology

a. Many types of inherited diseases in humans cannot be treated because little is known about the chain of events from the expression of the defective gene to the resulting disease. Retinitis pigmentosa, an inherited form of blindness, falls into this category. There is no treatment for this disease, which results in blindness in middle age for all who inherit the dominant gene. Researchers at North Carolina State University and Duke University have successfully produced transgenic pigs using genetic engineering that are providing an excellent genetic animal model for retinitis pigmentosa. Because of the size and construction of the pig eye, it makes an excellent animal model for the human eye.

b. Impact - Research is beginning to identify possible treatments for retinitis pigmentosa. Although much work must still be done, none of it would be possible without the transgenic pigs produced at North Carolina State University.

c. Source of Funds - Hatch, State and National Institute of Health

d. Scope of Impact - National

Key Theme - Plant Genomics

a. Current gene transfer technology is an uncertain art because we have little or no control over factors such as position effects and gene silencing interactions that can modify or abrogate transgene expression. These effects, which are sometimes first observed only several generations after the initial transformation, limit the applicability of transformation technology to plant improvement. We have developed technology that uses matrix attachment regions (MARs) to minimize certain aspects of this variation, and are attempting to define additional elements with similar, hopefully additive, effects. In addition, we are

working on procedures that will allow us to repeatedly target genes to the same location in the recipient genome. Future work may include attempts to transfer large segments of DNA, or even artificial chromosomes, in the hope of achieving more predicable gene expression.

b. Impact - If transgene behavior can be made more predictable we will be able to make better use of gene transfer techniques in plant improvement programs, as well as in fundamental research. One might reasonably anticipate an increase in the rate at which transgenic crop varieties are produces, as well as changes in the types of improvements that can be contemplated. For example, commercial transgenic cultivars commonly express single genes for resistance to pathogens or herbicide. In the future, we might contemplate transgenic plants that simultaneously express a dozen or more transgenes under appropriate developmental control and modify metabolic pathways or other complex quality traits. Such technology should considerably broaden the range of beneficial improvements that can be contemplated in plant breeding programs.

c. Sources of Funds - Hatch, State, USDA-CRGO, NSF

d. Scope of impact - National

Key Theme - Animal Genomics

a. Complex, or quantitative, traits are affected by multiple interacting genes that are sensitive to the environment. Most characters that are important for human health (for example, susceptibility to heart disease, cancer, or diabetes); agriculture (production and yield traits); and adaptation of populations to their environments are complex traits. A major challenge is to determine what are the genes affecting complex genotypes, as genetic methods of analysis developed for single genes with large effects are not appropriate. The use of model genetic systems, such as the fruit fly, *Drosophila melanogaster*, enables quick and efficient testing of new methods of analysis. The principle of conservation of genes affecting all fundamental biological processes means the genes affecting genetic variation of a trait in flies are likely also to be important for similar traits in humans and other organisms (for example, lifespan).

. Three methods have been used to map genes affecting several complex traits in *Drosophila* (numbers of sensory bristles, olfactory behavior, mating behavior, starvation resistance and longevity) and to determine their properties. Transposable element insertional mutations with quantitative effects have been induced, and the affected genes cloned using the transposable element as a molecular tag. Quantitative trait loci have been mapped by linkage to molecular marker loci in pedigreed populations. Finally, associations between molecular variation in candidate genes and phenotypic variation for the trait have been examined in random mating populations. Quantitative trait loci often have different and sometimes opposite effects in males and females, and in different environments. The chromosomal locations of quantitative trait loci often coincide with those of candidate genes, identified by mutations with large phenotypic effects. Association tests require a high density of intragenic polymorphic molecular markers, and reveal that regulatory gene regions affect variation for complex traits.

b. Impact - The complexities of quantitative variation in *Drosophila* impact the design of studies to determine genes affecting quantitative traits in humans and other organisms. It has been proposed that such genes can be mapped by genotyping a random sample of individuals for single nucleotide polymorphisms ('SNPs') in protein coding regions of candidate genes, and associating the genotype with

disease or other trait status. The work with fruit flies has shown that this strategy is likely to fail unless (1) the density of SNP markers is much greater than has been proposed, (2) markers are included in non-protein coding (regulatory) regions, (3) larger sample sizes are used, and (4) the effect of sex and other demographic factors are included.

c. Sources of Funds - Hatch, State, NIH, NSF

d. Scope of Impact - National

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$269,266	$4,329,938	$788,032	$482,002	11.3	41.2	64.4	15.0

Goal 1, Program Area 2:
Plant and Animal Germplasm, Genetic Resources and Conservation, and Plant Improvement

Subprogram Area 2a:
Crop Improvement

Overview

Research activities in this program area have concentrated on improving plant productivity and quality of fruits, vegetables and agronomic crops through breeding methodologies to increase yield and quality and reduce the incidence of diseases and insects; increasing biological efficiency through control of metabolic processes and gene regulation in plants used for food, fiber and fodder; and developing methods and strategies to more efficiently produce horticultural and agronomic crops in NC Some highlights of accomplishments in this program area are listed below.

- 'N7001' was released as the first drought-resistant cultivar released in the U.S.
- New soyfood cultivars were released for human consumption, including varieties N7101, N7102, N7103 and N6201.
- 'China Pearl', 'Challenger' and 'Intrepid' peach cultivars have been released with enhanced cold hardiness and thus will produce fruit even in seasons with late freezing temperatures.
- 'Sampson', 'Duplin', and 'Onslow' blueberries were released with superior characteristics for mechanical harvesting.
- The peanut cultivar 'Perry' was released with good yield and grade and moderate levels of resistance to various peanut diseases.
- 'Satelite', a soybean cultivar with low levels of linolenic acid and low saturated fat was released.
- Hulless oat germplasm was developed with good Hessian fly and Fusarium head blight for the horse industry.
- Powdery mildew resistant soft red wheat germplasm was developed and is being incorporated into cultivars. Leaf rust and septoria resistance has been transferred from wild diploid oat species to cultivated oats.
- Tomatoes are being developed with early blight and fusarium wilt resistances and enhanced color.
- Corn germplasm lines are being developed with gray leafspot resistance.

- Isolation of xanthotoxin from Xanthomonas is proceeding to elucidate the pathway leading to the production of cercosporin-line toxins.
- Protein kinases responsible for phosphorylating the SEC14-line lipid transfers protein Ssh1p were identified in soybean. The work is leading to osmoregulation of lipid synthesis, and has led to new insights into mechanisms plants use to recognize osmotic stresses, such as high salinity and drought.
- A new choline kinase isoform was isolated and characterized from soybean, a key enzyme of phosphatidylcholine biosynthesis pathway.
- Correlations between protein and isoflavonoid (a class of compounds with possible anti-cancer activity) concentrations were identified in soybean.
- Naturally occurring polyamines, were identified as well as the possible molecular basis for polyamine action as a plant growth regulator, and thus opens new approaches to controlling plant growth responses to agriculture.
- Methodology was developed to image soybean roots in situ using nuclear magnetic resonance imaging technology.
- Protein phosphorylation was studied with protein kinases and indicated that acetic amino acid residues flanking the serine can stimulate, while acidic amino acid residues generally inhibit phosphorylation. Proline residues near serine also inhibit phosphorylation.
- Vitamin A levels were correlated with ozone damage in snapbean.
- A PCR-based strategy was used to isolate isoforms of the FAD2 gene, encoding an oleic acid desaturase , from a high oleic acid soybean line.
- Glufosinate uptake in different weed species was investigated and up to 18-fold differences were observed. Differences in uptake and metabolism account for variation in fields for weed control.
- Weed management systems in herbicide-resistant crops, especially cotton, soybean and corn, were investigated as well as carry-over effects of alternative herbicides were investigated.
- HADSS (Herbicide Application Decision Support System) has been developed in as a Windows-based version and web-based version to provide an integrated weed management system in crops.
- Economic thresholds for ladysthumb and pale smartweed in cotton were determined and the competitiveness of these weeds is low.
- Field plots of transformed tobacco plants were processed for production of canine oral papilloma virus vaccine proteins and pilot-scale processing of proteins performed.
- The instability of a gene encoding a nicotine demethylase in burley tobacco and its effect on secondary amine alkaloids and tobacco-specific nitrosamines was investigated. Results indicate that a commercial crop could be produced from plants that do not have high mutation rates during tissue culture generations to manipulate ploidy levels.
- PCR-based markers to target intronic gene regions were developed and the allelic variation in intron, promoter, and exon lengths of 54 genes in each of 48 maize inbred lines were surveyed.
- Molecular markers were associated with freezing susceptible winter oats and proteins that increase the apoplastic fluid of frozen, winter-hardy oats were investigated for genetic sequences.
- Genes were identified in DuPont's proprietary soybean EST database that are candidates for influencing ER biogenesis during seed development.
- Soybeans were evaluated for soil water differential on utilization of N and variation was found for root branching and radial hydraulic conductivity among genotypes. Water use efficiency, measured as dry matter produced per unit water evapotranspired, was positively correlated with N utilization.
- Optimal N-uptake was investigated in corn by direct measurement and late in the growing season by color-infrared photography across different soil types.

- The effects of ozone and CO_2 exposure on plant development and plant/pest interactions were investigated. Elevated CO_2 was shown to alter needle chemistry and led to decreased site soil quantity of dry matter.
- The metabolic basis for high-oleic in and low 16:0 trait associated with the fap1 and fapnc alleles.
- A pedigree database for more that 550 North American soybean cultivars was established which documents relationships among lines for genetic enhancement.
- Experimental procedures are being developed to introgress exotic maize germplasm into elite corn lines by developing strategies to estimate new genetic variation in unadapted genotypes.
- Best linear unbiased predictions were used to calculate the breeding values of more than 200 cultivars and lines for flavor, and trends in flavor in germplasm developed during the past 60 years were determined.
- Tall fescue was genetically transformed with resistance to the herbicide 'Finale' and fungal resistance genes.
- Cyst nematode resistance in soybean lines was identified. Field designs were developed to control experimental errors for yielded in low-replication experiments.

Key Theme - Plant Genomics

a. Recombinant DNA technology holds great promise for the improvement of crop plants by adding genes for specific, well-defined traits such as resistance to pests or production of specific compounds such as vaccines. Several problems, however, remain to be solved before recombinant DNA technology can be routinely used for such improvements. One of these problems is that several crop species are difficult to transform by existing methods. Another problems is that even in plants that can be transformed readily, the introduced genes are often expressed at low rates or the expression is lost in progeny of the original transformant. Scientists at NCSU have studied the effect of flanking introduced genes with extra DNA sequences called MARs (Matrix Attachment Regions). These sequences appear to increase the expression of introduced genes, stabilize the expression in progeny of the original transformed plants and increase the efficiency of production of transgenic plants.

b. Impact - If this improvement in recombinant DNA technology applies generally to crop plants, the feasibility of using transgenic approaches will be greatly enhanced. Among other things, this technology should allow the production of crops with lower requirements for pesticides, thus lowering the environmental impact of farming. It should also make routine the engineering of plants to produce specific pharmacological compounds. Production of such compounds in tobacco might supplant traditional uses of tobacco and increase the value of the plants.

c. Sources of Funds - Hatch, State and NSF

d. Scope of Impact - National

Key Theme - Plant Germplasm

a. North Carolina farmers may choose from nearly 100 corn hybrids, 50 flue-cured tobacco varieties, 90 conventional soybean varieties, 60 Roundup Ready soybean varieties, 40 conventional cotton varieties, 20 Bt cotton varieties, 20 Roundup Ready cotton varieties, 40 wheat varieties and several barley and oat varieties when they decide what to plant each year, with new products coming on the market all the time.

Farmers must make the best possible crop decisions if they wish to maximize profit and keep their farms financially viable. The Official Variety Testing Program of the College of Agriculture and Life Sciences at North Carolina State University conducts performance trials on barley, corn, corn silage, cotton, flue-cured tobacco, oats, soybeans and wheat each year. Many of these varieties are new, so farmers do not know what to expect from them. The trials are located in major production areas of the state, using the same types of production practices and technology that farmers use. Data from the trials are collected and disseminated in Measured Crop Performance Bulletins, perhaps better known to farmers as "the green books." Nearly 20,000 copies of four different green books are printed annually. The information is also available on the World Wide Web.

b. Impact - The Official Variety Testing Program gives North Carolina farmers the information they need to make informed decisions about which varieties to plant to make sure they remain competitive in an increasingly competitive agricultural economy. While it is difficult to measure the impact of the Official Variety Testing Program, it seems likely the program fattens the bottom line of North Carolina farmers by several million dollars annually.

c. Source of Funds - Hatch, State and Smith-Lever

d. Scope of Impact - Regional

Key Theme - Plant Germplasm

a. The narrow of the genetic base of U.S. corn breeding is sufficiently limited that 20 private companies, including all major ones, have joined a private/public consortium to develop alternative sources of breeding materials. Crosses between promising tropical materials and private breeding lines have been made. Breeding families have been developed at N.C. State and top-crosses of these 50%-tropical, 50%-temperate families have been tested in cooperative yield trials conducted jointly by the NCARS, the USDA-ARS, cooperating universities, and private companies. Almost 4,000 families have been tested; over 800 of these families performed as well as the commercial checks in first-year yield trials. Of the approximately 600 families that have been tested for two years, about 70 meet or exceed the mean of the commercial checks.

b. Impact - The project (GEM, Germplasm Enhancement of Maize) represents the first and only industry-wide cooperative breeding effort. Seed requests from cooperators, both private and public, suggest that it is contributing to an expansion of the genetic base for corn breeding. Well over 100 requests have been made for specific breeding families, even before any announcements were made about seed availability. About 75% of these requests were by private, cooperating companies whose breeders had participated in growing the yield trials.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Expenditures and Personnel Commitments

Appropriations	Grants and Contracts	Personnel

Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$296,021	$2,963,713	$1,586,520	$957,616	15.5	47.8	26.9	10.3

Subprogram Area 2b:
Animal Improvement

Overview

Research was also conducted to improve animal performance by investigating basic biological systems that modulate life processes, studying the genome of animals, and creating useful animal models for the study of human and animal diseases. The impact of this research will enhance our understanding of the basic genetic and biological basis of animals, as well as improve the human condition via the study of animal models. One accomplishment in this program area is research that has shown the quantity and composition of fecal and urinary excreta in pigs is affected by genetic and sex influences indicating that there is a genetic component to the interaction of animal production and the environment.

Key Theme - Animal Genomics

a. Transgenic organisms are those that have received new DNA into their germ line via addition to the embryo. Transgenic plants have been front page news as genetically modified foods because of the controversy over food safety and their impact on the ecology where the plants are grown. Less well known is the research conducted with transgenic livestock being developed for agricultural and biomedical purposes. In agricultural the goal is to develop transgenic livestock with better efficiency of production and disease resistance. The mouse is used as a model to study the effectiveness of transgenes and the promoter that is used as a mechanism to activate the gene. Studies have centered on a growth hormone transgene constructed with a promoter that allows activation of the gene by adding zinc to drinking water. The purpose of these studies was to compare selection for increased growth rate in the presence of the growth hormone gene with conventional selection in the absence of the gene. The selection in different genetic backgrounds was also compared to see if this factor influenced the rate of genetic response. As selection progressed, the frequency of the growth hormone transgene was monitored to determine the reproductive performance of the transgenic mice.
b. Impact - This study has provided strong evidence that the growth hormone transgene would be more useful if used in a line not previously selected for increased growth. Evidence also was provided that the introduction of the growth hormone transgene had a negative impact on fitness of the animals. An important unanswered question is whether these observations were specific for this transgene construct we studied.

c. Source of Funds - Hatch, State and NSF

d. Scope of Impact - National

Key Theme - Animal Genetics

a. One of the most perplexing and frustrating challenges dairy producers face today is how to economically detect estrus and improve reproduction in high-producing Holsteins and other dairy breeds. Most research

has been aimed at hormonal interventions or use of expensive electronic equipment to identify cows in estrus. An assumption is that all AI bulls are equally fertile, a point that has proven to be false. Teaching and extension have emphasized environmental modifications as the most economical way for improvement in reproduction. It has been assumed that genetics variation in reproductive efficiency is nil, which our work has proved to be incorrect.

b. Impact - Use of AI bulls identified by Estimated Relative Non-return Rates as high conception will, on average, result in about 20% more calves per insemination. Advantages were apparent even in hot humid months in North Carolina and other states through the United States. Costs will be essentially the same per insemination, so economics of such bulls will likely be a reduction of direct and indirect costs per pregnancy of over 20%. Daughters of many dairy bulls, even some of those that sire higher producing daughters, have greater reproductive efficiency than the average AI bull. Combining these two procedures appears more cost-efficient than most if not all environmental interventions. All AI units have accepted these ERCRs (DRMS and NCARS) computed on mates of AI bulls as reliable.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$311,663	$720,813	$817,614	$200,861	4.1	9.8	10.7	2.5

Goal 1, Program Area 3:
Plant Protection Strategies

Subprogram Area 3a:
Forest and Horticultural Crop Protection

Overview

Research activities in this program area have concentrated on developing and enhancing pest, pathogen and weed management technology for growth and production of forests and horticultural plants for greater enjoyment and profitability in an environmentally sustainable manner; improving the understanding of ecology and genetics of pest, pathogen and weed populations and their interactions with plants and antagonists for more effective integrated pest management; and incorporating resistance to pests, pathogens and weeds into improved, productive cultivars through classical breeding and biotechnology/genomics. Some highlights of accomplishments in this program area are listed below.

- Several scientists attended a national meeting on bioterrorism. There is a potential for an ARS emphasis on this subject at NCSU in the Plant Science Unit. The disease forecasting program also has possibilities for prediction of aerosol delivery via wind currents.

- Plant health is a major effort of several departments in the College of Agriculture and Life Sciences at NCSU, including Entomology, Crop Science, Horticultural Science, and Plant Pathology. Integrated Pest Management continues to be a key component of many faculty programs. The Center for Integrated Pest Management has a regional influence on improving plant health.
- The Eastern USDA-APHIS Hub is now located on the NCSU campus as is the USDA-APHIS Center for Plant Health Science and Technology, which will enhance our work with invasive species. Recently, NCSU research has allowed establishment of export agreements with Japan for fresh market tomatoes.
- Plant-pathogen interaction research with root knot nematodes has shown that they contain a cellulose gene that is released into plant tissue via the nematode stylet during establishment of feeding sites. This is the first cellulase gene found in an animal. The gene has sequence similarities with bacterial genes indicating cross kingdom gene flow.
- The Micropropagation Unit is changing the NC sweetpotato industry by providing disease indexed mother plants for a new greenhouse sweetpotato vine propagation industry that provides true to variety, certified planting material for growers.
- Multidisciplinary teams are developing production practices for use as methyl bromide is phased out for strawberry and vegetable producers. The practices utilize sustainable agriculture techniques together with more environmentally friendly pesticides.
- A genome research laboratory was established that is allowing work on fungal, nematode, and bacterial pathogens to utilize genomics technology. Understanding the function of various genes is leading to ideas for novel management of diseases.

Key Theme - Plant Health

a. Flooding of sweet potato fields results in a condition known as "souring." This was a particular problem in North Carolina in 1999, when hurricanes caused extensive flooding and, consequently, extensive souring. Souring was thought to be caused by lack of oxygen in the root zone of sweet potatoes. As a result of research done at North Carolina State University, souring is now believed to be the result of a complex of factors, including fungal and bacterial pathogens in addition to flooding. The soilborne fungus *Geotrichum candidum* and a bacterium (putatively *Erwinia chrysanthemi*) were isolated consistently from soured sweet potato roots. Tests for pathogenicity of these two organisms were unsuccessful until roots were submerged in water for 24 hours following inoculation. *G. candidum* will cause low levels of disease by itself; however, when both organisms are combined in the inoculum, the resultant disease level is much greater.
b. Impact - Effective disease management is based on an understanding of the causal agents. The more complete understanding of the causal agents involved in souring developed by scientists at North Carolina State University should lead to strategies for minimizing sweet potato losses due to flooding. With the pathogens involved identified, it will be possible to screen sweet potato varieties for susceptibility to souring and to develop new varieties with high resistance to souring. Researchers will also determine which varieties are susceptible to souring and advise farmers to avoid these varieties.

c. Source of Funds - Hatch, State and Smith-Lever
d. Scope of Impact - Regional

Key Theme - Plant Health

a. In multidisciplinary work at the Center for Environmental Farming Systems, the effects of several production practices on naturally-occurring beneficial organisms (nutrient cyclers, arthropod predators, and insect pathogens) in the soil are being examining. Soil disturbance through tillage appears to be a major factor in disrupting populations of beneficial organisms. Tillage had a greater disruptive effect than conventional use of chemicals or organic practices in sweetpotato and other horticultural and field crops. The introduced insect-parasitic nematode, Steinernema riobrave, was able to persist for two seasons after introduction into corn in eastern NC, demonstrating its strong potential as an alternative to pesticides against soilborne insect pests. The introduced insect-parasitic nematode, Steinernema riobrave, was less susceptible to disruption by tillage than was the endemic nematodes, Steinernema carpocapsae and Heterorhabditis bacteriophora.

b. Impact - This result indicates that in some production systems, application of a biological control agent tolerant to disturbance may be more effective than conservation of endemic natural enemies. Increasing predictability and efficacy of biological control agents may reduce the need for synthetic insecticides, thus reducing the possibility of air, soil, and water contamination.

c. Source of Funds - Hatch and State

d. Scope of Impact - Regional

Expenditures and Personnel Commitments

(See Expenditures and Personnel Commitments at end of Subprogram Area 3b section.)

Subprogram Area 3b:
Agronomic Crop Protection

Overview

Research activities in this program area have concentrated on developing new and refining existing mechanisms and techniques for managing pests of field crops that are economically feasible for the producers and are environmentally compatible. Some highlights of accomplishments in this program area are listed below.

- Selection were made for resistance to tomato spotted wilt virus (TSWV) in peanut by evaluating resistance in Arachis species both by mechanical inoculation and through thrip vector transmission. Results indicated that cultivars with moderate levels of field resistance are highly susceptible to the virus after mechanical inoculation.
- Tests with cropping systems, including rotation, double cropping small grains and soybean, and no-till, show yield loss to soybean cyst nematode to be limited to about 5%.
- Studies on numerous transgenic field corn gene events with single and “stacked” genes for multiple Bt toxin expression demonstrated varying levels of protection against Helicoverpa zea ranging from poor to superior when compared to a commercially available single gene event variety.
- Field results across 7 to 10 locations for 5 years in the southern region for performance of bacterial and fungal biocontrol agents in control of seedling disease in cotton, snap bean show no single biocontrol agent controlled both Rhizoctonia and Pythium damping-off.

- Morning-glory, pigweed, and prickly sida seedling emergence from seeded populations was monitored in no-till plots with no debris (reference plots) or with crimson clover, subterranean clover, rye, or wheat debris. Cover crops were either desiccated by glyphosate or mowed and tilled into the soil. Surface debris treatments delayed weed seedling emergence compared to the reference plots. Rye and wheat debris consistently suppressed weed emergence; in contrast, the effects of clover debris on weed emergence ranged from suppression to stimulation.
- Plant growth regulators affected bentgrass lateral recovery from simulated injury with up to a 35% delay in recovery with certain PGR treatments whereas others have slightly increased recovery.
- Soybean varieties with resistance to race 2 of the soybean cyst nematode, *Heterodera glycines*, are currently under evaluation and development.
- A risk index to help peanut growers avoid preventive insecticide application for rootworm continues to be refined. Data from over 5 years show less than 5% of fields surveyed had economically damaging populations.
- A new technique for greenhouse screening of seedlings for resistance to rootworms has been developed which will increase the speed in which rootworm resistance can evaluated.
- Planting of native plant field borders around soybean and cotton fields as wildlife habitat resulted in lower populations of bollworm (Helicoverpa zea) and some beneficial insect species, and slighty higher levels of aphids and lygus bugs in adjacent crop edge rows.
- Initial studies to select for pyrethroid resistance in *Helicoverpa zea* in order to develop management strategies to control pyrethroid resistant bollworm have resulted in resistance levels of approximately 5-fold.
- A version of the weed management decision support system HADSS has been developed for cotton.
- Field experiments examining weed growth in N2-fixing soybean and peanut in sandy, low fertility soils have revealed that the weeds can acquire up to 70% of their nitrogen from the crop plants.
- Host-plant resistance to foliar pathogens of soybean has been demonstrated to effectively eliminate the need for protectant fungicides in soybean.
- A spatially explicit genetic model of *Helicoverpa zea* adaptation to Bt toxin, has had a two Bt toxin component added which has led to a first estimate of the frequency of Bt resistance genes in field populations of *H. zea*.
- A gene called CFP was isolated from the toxin producing fungal pathogen of soybean Cercospora kikuchii and shown to confer a significant level of toxin self-resistance in that organism. CFP provides self-protection by its action as a pump to rid the fungal cell of toxin.
- Research on plant viruses has shown that the virus encodes a movement protein, which is essential for the virus to move from cell-to-cell. Virion formation is required to achieve a systemic infection. Molecular determinants for virion formation and the function of the movement protein are currently being determined.

Key Theme - Plant Health

a. North Carolina peanut farmers used to protect their crops from a disease called leafspot by spraying fungicide at regular intervals on a predetermined schedule. Such spraying can be costly and sometimes unnecessary. Faculty in the College of Agriculture and Life Sciences at North Carolina State University came up with a better way of controlling leafspot. The disease infects crops only under certain weather conditions. By monitoring the weather, specialists were able to predict when the disease was likely to infect crops. Using this information, farmers spray only when disease outbreaks are likely.

b. Impact - Using the leafspot advisory, farmers can cut their fungicide use dramatically. Approximately 75 percent of North Carolina peanut growers now use the advisory to determine when to apply fungicide. Depending on the weather in a given year, North Carolina farmers save from $1 million to $2 million in fungicide costs. Similar pest outbreak prediction systems have been developed for and are being tested on other crops across the Southeastern United States. At the same time, advances in computer hardware and software are making it easier for farmers to get this information. And advances in weather forecasting promise to make the information yet more useful by enabling pest outbreak predictions days from an actual outbreak.

c. Source of Funds - Hatch, State and Smith-Lever

d. Scope of Impact - Regional

Key Theme - Plant Health

a. Among the most effective products of genetic engineering has been what are known as Bt crops. Genes from a bacterium, Bacillus thuringiensis (Bt), that code for the production of insecticidal proteins have been engineered into the chromosomes of crops. The resulting transgenic cotton, corn and potatoes that contain these genes produce the insecticidal proteins from the seedling stage until harvest, and this effectively protects the crops from specific pests without disrupting beneficial insects and wildlife. The use of these crops has reduced insecticide use and has resulted in economic benefits for farmers and agribusinesses. Unfortunately, there is field and laboratory evidence that insects can evolve resistance to these Bt proteins. If resistance develops, farmers may need to return to the use of conventional insecticides, which tend to be much more environmentally disruptive than engineered crops. For well over a decade, scientists at North Carolina State University have studied ways to develop and use Bt crops that decrease the risk of rapid pest adaptation to the Bt toxins. This work has involved both theoretical and empirical research. All of this information has been shared with other researchers in the Environmental Protection Agency, U.S. Department of Agriculture, other universities and industry in order to develop practical approaches for decreasing the risk of resistance while ensuring the economic and environmental benefits of this technology. An ongoing research collaboration with the International Rice Research Institute has provided scientists and regulatory officials from developing nations with a better understanding of issues related to the sustainable use of Bt-producing rice and cotton.
b. Impact - The detailed research findings from North Carolina State University have been instrumental in convincing the EPA and industry that there are ways to get long-term benefits from Bt toxin-producing crops. NC State University scientists have participated in numerous public and private workshops and conferences aimed at educating diverse stakeholders about the benefits of reducing the risks of rapid pest adaptation. This has resulted in the EPA mandating the use of specific resistance management approaches by all farmers who plant crops that express the Bt toxin. The institutionalization of resistance management has been a major step for agriculture because these policies require farmers to sacrifice a certain amount of short-term profit for long-term benefits.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Expenditures and Personnel Commitments (Subprogram 3a and 3b)

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$536,132	$6,820,786	$1,737,473	$1,728,827	27.2	48.6	46.0	31.9

Goal 1, Program Area 4:
Animal Diseases and Animal Health

Overview
Research activities in this program area have concentrated on improving overall animal health and performance through methods that reduce the incidence and/or severity of diseases caused by pathogenic agents and/or other environmental factors; developing environmentally safe, economically realistic, and socially acceptable methods for the handling and recycling by-products of food animal industries; and developing effective, safe and acceptable practices for the control of odor and pests associated with food animal production. Some highlights of accomplishments in this program area are listed below.

Isolated, purified and characterized two putative viral agents associated with Poult Enteritis and Mortality Syndrome (PEMS) in turkeys. One agent is an astrovirus and the other is a reovirus. While both of these viruses have been known to be involved in enteric disorders of poultry, the significant and common finding by these investigators is that both agents induce significant detrimental immune alterations in exposed SPF poults.

Examination of piglets exhibiting rotaviral gastroenteritis, one of the leading causes of neonatal intestinal injury and diarrhea, with the ultimate goal of improving the rate and extent of recovery.

Characterization of a group of mutations that truncate the membrane spanning domains of togavirus membrane glycoproteins. The togaviruses are a major group of infectious agents that cause disease in man and domestic animals. Among these are horse encephalitis, classical swine fever, border disease and bovine diarrhea.

Completion of an evaluation of the house fly's ability to harbor and transmit *Yersinia pseudotuberculosis*, an infectious bacterium of turkeys. House flies can support this bacterium for 30 hr on the body surface, and in the gut for up to 36 hours.

Investigation of the mechanism by which tetracycline, spectinomycin, and other antibiotics act on the structure of the ribosome in *E. coli*.

Development of on-farm mortality preservation and conversion into value-added animal feed products. Procedures were developed for preserving mortality carcasses by phosphoric acid and processing it into a protein by-product meal by flash dehydration and extrusion processing.

Studies on the use of microbial phytase in poultry feeds in order to reduce phosphorus excretion.

The impact of field incorporation of turkey litter on the survival of darkling beetles was evaluated and soil incorporation of the litter significantly reduced beetle survival.

IPM is being used to reduce cockroach infestations on swine farms, and to reduce the amount of pesticides used in their control.

Molecular markers related to stress are being studied in an attempt to revitalize stocks of the American oyster. Heat shock proteins (Hsps) are essential for adaptation to thermal, chemical and biological stressors in many organisms.

Peptides can enhance intestinal nutrient absorption when administered *in ovo* or post-hatch.

Studies to determine the molecular mechanisms associated with the induction of morphological defects in mice have been conducted which demonstrate the role of aberrant gene expression in the etiology of morphological defects.

Key Theme - Animal Health

a. Integrated management of pests of importance to livestock and poultry requires the broad understanding of diverse management tools including cultural, physical, biological and chemical control methods. Although chemical pesticides play an important role in the management of livestock pests under outbreak conditions we recognize the importance of minimizing pesticide exposures under the Food Quality and Protection Act. In addition reduced use of pesticides lessens the potential of pesticide resistance to develop in a pest population. The goal of this research is the incorporation of these alternative methods into Integrated Pest Management Programs for poultry and livestock. The turkey industry in North Carolina has been confronted with emergence/re-emergence of two important diseases, Poult Enteritis Mortality Syndrome (PEMS) and Turkey Coronavirus (TCV). PEMS is a devastating enteric disease of turkeys of an unknown etiology, and is often, but not always, associated with TCV. Although a cure for PEMS has not been determined the incidence of disease has declined in recent years. Mechanisms associated with the transmission of these diseases may be closely linked and insects may be directly involved. The darkling beetle (*Alphitobius diaperinus*) and the house fly (*Musca domestica*) are commonly associated with turkey litter. The role of these insects in the transmission of these diseases, and its movement and dispersal habits are largely unknown.

. Research at NCSU used immunofluorescent (FA) and serology techniques to detect TCV in turkey tissues. Results indicate limited transmission TCV to turkey poults by darkling beetles, however darkling beetles do readily transmit PEMS agents to young turkeys. Potential for disease transmission is greater in house fly. TCV remains viable in house flies for a longer period than in darkling beetles, and the potential for dispersal is greater. Currently studies are being conducted to mark and recapture the immigration of darkling beetles from field to turkey house following the land application of organic fertilizer. Establishing a link between the application of turkey litter and immigration of darkling beetles may provide important clues to the spread of poultry diseases in North Carolina. Darkling beetle survival was significantly impacted by mechanical incorporation of litter into red clay field soils. Temperature has a great impact on beetle survival. Results of this technique may vary with soil type. Surviving beetles dispersed from the field by flight. Dispersal is limited by temperature.

b. Impact - Turkey Coronavirus (TCV) is subject to rapid destruction in the environment. Adult darkling beetles transmit TCV mechanically for only a few hours. Transmission of the agent(s) responsible for PEMS was mechanically transmitted for 24 hours and perhaps longer. The darkling beetle is added to the list of known vectors of this disease. This project provides definitive information on the role of darkling beetles in the epizootiology of TCV and perhaps PEMS. Using methodology developed in this initial study, the house fly was also incriminated in the transmission of TCV. Further study will define the role of the house fly in TCV epizootics in NC.

c. Sources of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Emerging Infectious Diseases

a. Research in aquatic plant ecology and nutrient pollution impacts on freshwater, estuarine, and marine ecosystems has lead to the co-discovery of the toxic dinoflagellate, Pfiesteria piscicida, as a causative agent of major estuarine and coastal fish kills. This organism was the first toxic dinoflagellate known to have direct attack behavior toward fish; the first to have a complex life cycle with many forms; the first with toxicity triggered by live fish or their fresh tissues; and the first to produce neurotoxic aerosols that can cause serious, mostly reversible cognitive impairment and short-term memory loss in humans, as well as certain more long-term impacts on the human immune and autonomic nervous systems. In 2000, work was initiated to characterize the genome of P. piscicida and the second known toxic Pfiesteria-like species, which was named as P. shumwayae. Also work is nearly completed on purification of a potent neurotoxin from P. piscicida, and the determination one of its major modes of action in causing 'crossover' impacts on mammalian nervous and immune systems. Also documented was additional chronic, severe impacts of Pfiesteria toxin in promoting finfish disease; and, verification that Pfiesteria thrives after being consumed, then excreted in feces of adult oysters -- which means that cultured, transported oysters can serve as a vector in distributing Pfiesteria to other regions. And, for the first time, research has verified toxic strains of Pfiesteria species in northern Europe and in New Zealand.

b. Impact - Research on Pfiesteria and water quality has provided the framework that was used by the U.S. Congress and federal agencies in direct more than $600 million to control pollution in estuaries and coastal waters in many states. In 1999, the US Department of Agriculture committed to direct $221 million to North Carolina's Albemarle-Pamlico Estuarine Ecosystem to help reduce agricultural pollution. In support of this research, during 1998 the U.S. Congress appropriated $500,000 to our laboratory to continue the research effort (received in 1999); and the North Carolina General Assembly directed $1 million in non-recurring funds, and $600,000 in recurring funds to NCSU to form a Center for Applied Aquatic Ecology. This Center will address applied issues spanning from enhancement and protection of fish nursery habitat to human health impacts from Pfiesteria. Its research will focus on impacts of algal blooms on aquatic food webs, especially on commercially important fish species and their habitats, and on the health of humans who utilize these aquatic resources. The Center's research will examine direct and indirect influences of pollutants such as nutrients, suspended sediments, and pesticides on algal blooms, fish stocks, and valuable fish habitat species. The Center will also meet a pressing need in obtaining data to develop improved management strategies to enhance habitat for fish yield, and to mitigate impacts of noxious algal species that have been stimulated by wastes. It will contribute data that are of practical use to policy makers in evaluating both primary and secondary impacts of human and animal wastes on our freshwater, estuarine, and marine resources.

c. Sources of Funds - Hatch, State, NSF, USDA Special Grants

d. Scope of Impact - National

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$767,875	$2,135,119	$893,492	$503,422	11.2	18.7	16.3	11.0

Goal 1, Program Area 5:

Farm Business Management, Economics and Marketing

Overview

North Carolina farmers are facing major structural adjustments due to changes in farm programs and traditional "cash crop" quota reductions. Research projects on cotton and tobacco production systems were begun to aid farmers in their decisions on what new enterprise or crop rotation to add to farming operation. Cost of production numbers were developed for tobacco and cotton enterprises. The difference in prices of pesticide products that are chemically identical, but can not be shipped across country borders has caused farmers and others on either side of the US-Canada border to complain. Farmers on either side of the border who grow the same crops do not have access to the same pesticides, or if available, at a higher price. Research was conducted to evaluate reasons for price differences and to assess the effects of price differences on the cost of production. Results showed the economic impact of price differences in pesticides on the total pesticide costs to farmers were small because farmers were able to substitute pesticide products and use more mechanical pest controls. Price differences were found, some were higher in Canada, some were lower. The price difference summaries showed that they were often higher between US-Canada that between US locations.

The 1996 Fair Act resulted in significant changes to US government programs of the support of agricultural incomes. These changes included the elimination of many forms of supporting producer prices and incomes. The federal crop insurance program, however, realized an expansion as revenue insurance contracts replaced traditional yield insurance contracts. Research was conducted that rates crop insurance by using price and yield risks that can be used for achieving actuarially fair crop insurance rates. The results suggest that risk management programs have served as an inducement for farmers to plant on erodible land. During a period where the Conservation Reserve Program has significantly reduced much soil erosion, expansion of crop insurance and disaster relief programs offset approximately 60% of the reduction in erosion. These results have been used to make changes to actuarial methods used to rate insurance programs that should make insurance premiums more accurate and thus improve the operation of the programs (which direct billions of dollars in support to agricultural producers). The research has the potential to result in significant saving for taxpayers.

The majority of North Carolina's strawberry crop is sold through direct market channels such as Pick-Your-Own or Ready-Pick operations. Few managers know the socioeconomic characteristics of their customers or have ever assessed the effectiveness of their advertisement campaigns. Customer surveys were conducted at 8 direct market strawberry operations during the past season. Information gathered and analyzed has been made available to strawberry marketers. These managers can change their services, product offerings, and advertising programs to better promote their strawberry operations.

The county by county effects of the tobacco settlement (in North Carolina) and possible elimination of the tobacco program were researched. The results suggest that if cross-county restrictions were lifted in NC, tobacco production would fall by 3% in the Border Belt, increase by 10% in the Eastern Belt, fall by 15% in the Middle Belt, and fall by 15% in the Old Belt. Lifting the restrictions would result in increases in quota income to the Middle and Old Belts by over 20% and by 4% in the Border and in decreases in quota income in the Eastern Belt. While quota owners would benefit in the Middle and Old Belts, farmer incomes in those belts would fall by 16% (Middle Belt) and 15% (Old Belt).

As North Carolina continues to urbanize, there is concern that unique land resources, open space and viable agriculture and forestry will be lost. A project was completed which identifies legal and financial tools that can be used to preserve these resources and promote the continued viability of agriculture and forestry in North Carolina. A **Land Preservation Notebook** was published to serve as a catalog of federal and state land preservation programs, laws and regulations available for landowners and others.

Key Theme - Agricultural Competitiveness

a. With the removal of much of the safety net that previously existed for farmers in the 1996 Farm Bill, farmers are more susceptible to unfavorable commodity price movements. This fact coupled with low commodity prices for corn, soybeans and wheat have produced an increased demand by farmers for the knowledge and skills required to better market their crops. Many farmers consider marketing their weakest area of knowledge. In order for farmers to make fully informed decisions concerning marketing grain crops and reducing exposure to price risk, understanding how local prices and basis have behaved historically is extremely important. A historical database for soybean and corn prices by location for North Carolina over the period 1980-1999 was developed and is continually updated. This database allows the calculation of basis, which is critically important to grain marketing decisions. These basis tables are available as part of the North Carolina Soybean and Corn Price Yearbook and have also been made available on the web at the North Carolina State Grain Marketing Homepage.

b. Impact - These data combined with the educational materials available give farmers and others the necessary tools and ability to make more informed and better marketing decisions. For example, the yearbook gives farmers a knowledge of historical basis that can be used to decide whether to accept or reject a particular forward price offer, to decide whether to hedge using futures, or to store their crops for a deferred sale. These data will also serve as an extremely useful resource for analyzing other important economic questions.

c. Source of Funds - Hatch, State
d. Scope of Impact - State

Key Theme - Agricultural Profitability

a. Since its introduction, the adoption of genetically altered Bt, or Bollgard cotton, by North Carolina producers has grown steadily, from 24,000 acres in 1996 to just under half a million acres in 2000, or more than half the state's record 900,000-acre cotton crop. Because bollworms are North Carolina's major cotton pest and because Bollgard cotton is only moderately resistant to this pest, North Carolina's producers must carefully weigh the high technology costs of planting Bollgard cotton (presently averaging about $20 per acre, or as much as $10 million in the 2000 crop year) against the potential benefits of this new technology. Additionally, due to the lower insecticide use with Bollgard cotton and its variable efficacy against other pests (Bt cotton provides exceptional control of tobacco budworms and European corn borers but no control of non-caterpillars), dramatic shifts have occurred in the status of many North Carolina cotton pests. Therefore, grower decisions about the potential economic returns of Bollgard technology are difficult. North Carolina Cooperative Extension Service specialists in the College of Agriculture and Life Sciences at North Carolina State University conducted a comprehensive statewide survey of 360 Bollgard and 360 conventionally managed cotton fields from 1996 to 1999 to determine the

degree of late-season boll damage caused by bollworms, European corn borers, fall armyworms and stink bugs. This survey was accompanied by the canvassing of a sample of North Carolina's independent crop consultants, producers and North Carolina Cooperative Extension agents to obtain data on insecticide use against various cotton pests, technology fees and scouting requirements in conventional and Bollgard systems over this four-year period. The insect damage caused by major pests, the insecticide use patterns and the technology fee assessments were used to form the basis for economic comparisons of Bollgard and conventional cotton insect management systems in North Carolina.

b. Impact - Armed with objective information quantifying shifts in the importance of our major insect pest species on cotton (bollworm damage to bolls has dropped 60 percent, while stink bug damage to bolls is up four-fold in Bollgard cotton) and significant changes in insecticide use patterns (Bollgard cotton was treated an average of .75 times compared with 2.61 applications for conventional cotton from 1996 to 1999), North Carolina producers and consultants now have the information they need to make informed decisions about the expected costs and benefits of this new Bollgard technology.

c. Source of Funds - Hatch, State and Smith-Lever

d. Scope of Impact - Regional

Key Theme - Managing Change in Agriculture

a. Many poultry contract growers are dissatisfied with existing contractual arrangements. Their complaints focus primarily on tournament schemes, under which growers receive a fixed amount per pound of live meat produced (to defray their capital and operating expenses), plus a bonus payment for using integrator-provided inputs efficiently. Poultry growers have repeatedly expressed concern about tournaments because they believe that it is unfair to compare their production costs with those of other growers in determining payments. Some growers have argued that tournament schemes are biased, since integrators have sole control over the initial quality of production inputs. Consecutive flocks grown by the same grower, and having similar production costs, can receive substantially different payments, depending on the performance of other growers in the settlement group. Growers have expressed exasperation over this form of remuneration since they have no way of anticipating how large their payments will be.

. Analysis of the welfare implications of contemplated government regulation of poultry contracts have indicated that the mandatory replacement of tournaments with fixed performance standards would a) increase grower welfare, and b) increase or decrease the social surplus. This shows that whereas the mandatory replacement of tournaments with fixed performance standards, absent any other rules, can decrease grower income insurance without raising welfare, income insurance and welfare can simultaneously be increased provided that the slope of the bonus payment scheme, the so called "piece rate," is also regulated. Moreover, the enforcement of fixed performance standards absent any rules for the magnitude of the piece rate will result in an unambiguous reduction in social surplus, but regulation accompanied by a rule determining the magnitude of the piece rate may or may not reduce social surplus, depending on the technology and preferences.

b. Impact - If the public policy in this area is to receive sufficient guidance, it is essential that it relies on economic research of this kind. The obtained results provide an accurate account of the welfare implications of a concrete regulatory proposal and gives a specific set of instructions how to proceed. The

idea of simply imposing a mandatory use of fixed performance schemes in settlement of broiler contracts will not achieve a targeted goal of improving the welfare of growers. A fairly elaborate scheme that requires the regulation of the "piece rate" will have to be introduced instead. A substantial opposition from the integrators' circle should be expected because the companies will be worse off under this scheme.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Niche Market

a. The majority of North Carolina's strawberry crop is sold through direct market channels, such as Pick-Your-Own and Ready-Pick operations. However, few managers know the socioeconomic characteristics of their customers or have ever assessed the effectiveness of their advertisement campaigns. Therefore, they do not know who their customers are, if they are receiving the desired results from their promotional efforts, or if they are spending their advertising dollars wisely. Consumer surveys were conducted at eight direct market strawberry operations during the 1999 marketing seasons. Customers were asked if they could recall any recent advertisements and if the ads had an impact on their decision to shop at the garden center. The amount of fruit the customers purchased, amounts spent during the shopping trip, and selected consumer socioeconomic characteristics were also collected.

b. Impact - Direct market strawberry operators now have more information to help them make more informed marketing decisions. They have a better understanding of their "typical" customers, how far they travel to pick or buy fruit, and the most effective advertising means of reaching their target customers. Consequently, managers can change their services, product offerings, and advertising programs to better promote their strawberry operations. The operators also know how to improve the effectiveness of their advertising programs and how to attract new customers by focusing on the reasons customers buy direct market fruit and by informing working couples that pre-picked fruit is available.

c. Source of Funds - Hatch, State

d. Scope of Impact - State

Key Theme - Risk Management

a. With the removal of much of the safety net that previously existed for farmers in the 1996 Farmbill, farmers are now more susceptible to unfavorable price movements. This fact, coupled with low commodity prices for corn, soybeans, and wheat has resulted in an increased demand by farmers to gain the knowledge and skills required to better market their crops. Many farmers consider marketing as their weakest area in their farm enterprise. In order for farmers to make fully informed decisions concerning marketing grain crops and reducing exposure to price risk, understanding how local prices and basis have behaved historically is extremely important. A historical database for soybean and corn prices by location for North Carolina over the period 1980-1999 has been developed and is being continually updated. This database allows the calculation of basis which is critically important to grain marketing decisions. These basis tables are available as part of the North Carolina Soybean and Corn Price Yearbook and have also been made available on the web at the North Carolina State Grain Marketing Homepage.

b. Impact - These data combined with the educational materials available give farmers (and others) the necessary tools and ability to make more informed and better marketing decisions. For example, the yearbook gives farmers the knowledge of historical basis that can be used to decide whether to accept or reject a particular forward price offer, to decide whether to hedge using futures, or to store their crops for a deferred sale. These data will also serve as an extremely useful resource for analyzing other important economic questions. For example, this data is also being utilized in the development of the CropRisk, the software tool that is being developing as part of the risk project that the department has received funding for from the USDA. Finally, since this information has been made available for over a year now and I have used it in my extension programs I have had much positive feedback from producers who are utilizing this information in making marketing decisions. For example, numerous producers have shared with me that this information has allowed them to increase their bottom line significantly. In particular, one producer shared that it was worth more than $1 per bushel (about a 20 per cent increase) on their net soybean price due to the strategy he successfully adopted as a result of this information and marketing programs he attended.

c. Source of Funds - Hatch, State

d. Scope of Impact - Regional

Key Theme - Agricultural Financial Management

a. The difference in the prices of pesticide products which are chemically identical, but can not be shipped across country borders has caused farmers and others on either side of the US-Canada border to complain. The concern is that farmers on either side of the border who grow the same crops do not have access to the same pesticides, and if they are available they are higher priced. This condition can lead to differences in costs of production and profitability for farmers of key crops such as wheat, barley, potatoes and canola. At the request of the US Department of Agriculture and Agriculture and Agri-Food Canada a study was initiated by G. Carlson, NCSU, and McEwan of Guelph University to study the price differences of pesticide products between the US and Canada. The three objectives of the study were: 1) to assemble information on price levels for all major pesticides used on wheat, barley, potatoes and canola in the US and Canada, 2) to evaluate reasons for price differences between locations, and 3) to assess the effects of price differences on the cost of production of crops. The information was assembled into a report and orally presented to USDA and AAFC. A Senate Agriculture hearing was held to consider the study and possible legislation to allow shipment of pesticides across the US-Canada border.

b. Impact - The economic impact of price differences in pesticides on the total pesticide costs of farmers were small because farmers were able to substitute pesticide products and use more mechanical pest controls. We did find price differences for various pesticides. Some were higher in Canada, and some were lower there. The economic explanations for higher prices included higher willingness to pay in some areas (demand), higher cost to produce and sell the products, price discrimination by sellers, patent protection differences and differences in the prices of substitute pesticides. The price difference summaries showed that the price differences were often higher between US-Canada locations than between US locations. However, over time, pesticide price differences sometimes favored US farmers and sometimes favored Canadian farmers. The findings did not imply that legislation is needed.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$218,210	$902,699	$142,910	$76,896	4.8	5.6	4.0	3.3

Goal 1, Program Area 6:
Product Development

Overview

Activities in this program area in 2000 have concentrated on development of new and improved animal and fruit and vegetable products, reduction of waste through development of by-products. It is envisioned that new products and/or processes will be adopted by industry leading to economic expansion by way of domestic and international sales of North Carolina and other U.S. value-enhanced agricultural products. Single-event economic impact can be equated to a $20 million or greater increase in sales. Some highlights of activities in this program area are listed below.

- Fat soluble vitamins are often removed due to reduced fat products. A milk protein, β-lactoglobulin, has been shown to bind with these vitamins and thus provides a new vehicle to low-fat product fortification utilizing dairy product components.
- Studies have shown that many fruits and vegetables contain antioxidants that can reduce free radicals associated with degenerative diseases. Processing techniques are being optimized to maximize the antioxidant content and quality of several North Carolina fruits, along with development of an antioxidant nutrient database of North Carolina fruits.
- Quality retention and shelf-life extension have been achieved for North Carolina blueberries by washing with ozonated water.
- A new procedure modified whey protein concentrate using hydrolysis, gelation, freeze-drying and grinding to impact starch-like functionality to fluid systems. Over a broad range of pH and temperature conditions, these dairy-based ingredients significantly lower processing costs.
- Biological nitrogen fixation can provide an economic and environmentally safe source of this nutrient for efficiently nodulated leguminous species. This can be especially advantageous in tropical soils which are generally low in available plant nutrients. Leguminous forage species adapted to the soils and capable of high nitrogen fixation may therefore have an important impact on pasture-base animal production system. Work has indicated that effective selection of *Bradyrhizobium* strains for *A. pinto*: improves dry matter yield and forage quality.
- Research has shown that the quality of shredded sweetpotato can be maintained for 14 days of storage at 4° C, thus allowing expanded market for all grades of these roots.
- Protein functionality and applied rheology studies are placing emphasis on how modifications alter gelation of whey proteins, thus finding new uses for these proteins.
- It was shown that the antioxidant enzyme, FeSOD, protects aerobic organisms against the toxicity of oxygen free radicals, thus improving their biological function in dairy foods.

- The Southeast Dairy Foods Research Center has generated substantial information and new technologies that have practical impacts in the areas of whey protein functionality, dairy probiotic cultures, and development of a cheese-flavor lexicon.
- Adding value to poultry feathers has been addressed by isolating bacteria and their proteases that degrades at low temperatures (15-30° C). Feather meal can replace soybean meal up to the level of 7% dietary protein with a U.S. market potential of $400 million a year.
- Work continues on investigating new uses and products for tobacco. A papillomavirus vaccine has been expressed in transgenic tobacco plants. Extraction and marketing of such vaccine and other high-value proteins, along with other valuable components of the tobacco plant, could help to develop alternative markets for tobacco growers.

Key Theme - Adding Value to New and Old Agricultural Products

a. Proteins and polysaccharides (complex carbohydrates) provide foods with structure and nutrition. Whey proteins from milk have high nutritional value, but lack in some chemical and physical properties to function in certain food applications. The goal of this research program is to provide the fundamental scientific understanding of factors determining the texture, appearance and stability of foods, and how whey protein ingredients can be modified to achieve desired functions. There is a worldwide market in whey-based ingredients. Those high in protein are called whey protein concentrates (which contain 35-80% protein) or whey protein isolates (which contain > 90% protein). At NCSU, research has determined the mechanisms responsible for gelation of whey proteins.

b. Impact - Gelatinzation of whey proteins is the major reaction used to create texture in many foods and it has been shown that whey proteins can be heat-processed into polymers that have unique functional properties. Polymer-based whey protein ingredients can be used in products that previously required polysaccharide ingredients. This technology will allow for developing products with improved nutritional and textural quality.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - New Uses for Agricultural Products

a. North Carolina farmers are faced with finding alternative, cash crops such as fresh fruits and vegetables to provide supplemental income. As these crops are seasonal, little emphasis has been placed on developing these raw materials into value-added products for the nutraceutical and food industries. Research studies show that fruits and vegetables contain antioxidants that can reduce free radicals associated with degenerative diseases such as cardiovascular diseases, diabetes, cancer and others. NC ranks 4th in nation in strawberry production with significant production of muscadines, apples, and blueberry. However, few of these products are processed into value-added products. Initial studies developed methods to determine the antioxidant capacity of selected fruits and to examine the effects of processing on the antioxidant content of blueberries, strawberries, and muscadine grapes. The goal is to optimize the antioxidant content of these fruits through further processing of selected fruits into raw materials for the nutraceutical industry. Methods to measure the antioxidant capacity of fruits have been developed and when applied to blueberries and grapes, show that significant improvements in antioxidant retention in juices and wines can be obtained.

b. Impact - The expansion of North Carolina's fruits production and processing industries to provide more fruits for retails sales and for further processing into value-added products will provide more income to farmers, their local communities and to the State as a whole. Optimizing processing techniques to maximize the antioxidant content and quality of fruits will expand production and processing. Development of an antioxidant nutrient database of NC fruits will increase consumer knowledge of the nutrient composition of fruits resulting in greater consumption of fruits and a healthier populace and a more productive economy for the State and the nation.

c. Source of Funds - Hatch, State

d. Scope of Impact - Regional

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$135,342	$1,111,677	$336,827	$157,306	5.4	12.7	8.2	5.0

National Goal 2:
A Safe and Secure Food and Fiber System

Program Area 7:
Food and Fiber Processing, Safety and Quality

Overview

Research activities in this program area have concentrated on identifying problems and solutions to quality maintenance in storing and marketing fruits and vegetables, field crops and animal products; ensuring that food

products are free from toxic contaminants; and protecting food and feed supplies from harmful microorganisms and naturally occurring toxins. Some highlights of accomplishments in this program area are listed below.

- Crude evening primrose seed extracts were shown to contain antioxidant activity comparable or equivalent to some commercial antioxidants.
- Process technology was developed using carbon dioxide to rapidly cool eggs from 100 F to 45 F in less than 90 seconds compared to 5-14 days for traditional methods of egg cooling.
- A new procedure using whey protein isolate was developed to modify whey protein concentrate to impart starch-like functionality to fluid systems.
- A relationship between the quality of canola oil and the resulting convective heat transfer coefficients was determined.
- Heating liquid and suspended particles were found to be more uniform in temperature when heated using RF energy than with microwave energy.
- Correlations were developed to predict the convective heat transfer coefficient in a helical heat exchanger for different process temperatures, flow rates, and coil diameters.
- A new method for determination of convective heat transfer rates from a carrier fluid to a solid particle during aseptic processing has been developed based on ablation heat transfer.
- Adjustment of brined cucumbers to pH 3.5 was found to result in optimum textural and microbial stability during long-term storage.
- Cucumbers were successfully fermented in the absence of salt, provided they were blanched and inoculated with a selected culture of lactic acid bacteria.
- Nuclear magnetic resonance research on immersion frying has resulted in development of a technique for quantifying oil age non-invasively.
- Technology has been developed for a one-step purification and immobilization of recombinant enzymes from crude fermentations which will minimize the cost of preparation of bioreactors.
- Processes have been developed to control the textural properties of processed sweetpotato.
- Peanut hull brightness was found to decrease with longer windrow curing times and in some cases to decrease with higher temperature of the drying air.
- Computer models have been developed for moisture removal, chlorophyl degradation, starch hydrolysis, and respiration as a function of temperature, humidity, and air flow rate in tobacco curing.
- Eight peanut breeding lines have been identified that are good candidates for transmitting superior roasted flavor quality characteristics to their progeny.
- The use of cyclopropenes is a new way to inactivate the ethylene receptor and extend the life of fruits and vegetables as well as flowers.
- A technique for concentrating two bacterial pathogens from dairy commodities has been developed using zirconium hydroxide.
- Models have been developed to predict the risk to human health associated with poor handling practices of ready-to-eat foods.
- Models have been developed to assess the risk of fumonisin contamination in shelled corn.
- Techniques have been developed for sampling for genetically modified seed.
- Procedures for predicting the concentration of deoxynivalenol in corn have been developed based on testing levels in the corn fines.
- Nisin supplements were found to inhibit Bacillus cereus spores in skim milk, Bacillus stearothermophilus spores in a chocolate milk drink, and Listeria monocytogenes on fresh pork loin.
- The addition of 1.3 ppm of chlorine dioxide to cucumber hydrocooling water was found to prevent the build-up of microorganisms.

- Sulfur compounds present in cabbage and sauerkraut were found to possess antimicrobial activity against some food pathogens.
- Casted edible films derived from corn zein and containing the microbial inhibitors lauric acid and/or nisin have been found effective in reducing the population of Salmonella typhimurium organisms.

Key Theme - Food Handling

a. North Carolina is the largest producer of sweetpotatoes in the U.S. and is one of only a few states that provides a year-round source of sweetpotatoes to consumers. This is due largely to the use of horizontal ventilation facilities (HVFs) developed by NC State researchers and implemented by growers and packers during the 1990's. These facilities tightly control the temperature and relative humidity necessary for postharvest curing and long term storage of sweetpotatoes. An HVF is generally comprised of multiple rooms with each room handling approximately 600,000 kg of sweetpotatoes. Previous research has shown that an HVF can more than double storage yields during off season months as well as extend sweetpotato storage life. One of the primary limitations to the expanded use of HVFs is the high energy cost associated with their use of refrigeration. Refrigeration is required for greater yield and storage time, but its use reduces profits to the processors. The goal of this study is to reduce energy usage and further improve the design and management of sweetpotato horizontal ventilation facilities (HVFs) in North Carolina using computer simulation. The advances made will provide the sweetpotato industry access to a new tool that will help them to more efficiently manage a vital North Carolina commodity.

. Evaluation of design alternatives before building construction can result in significant savings to the postharvest sweetpotato process but is difficult due to the complex nature of the facility. Refining control strategies to minimize use of mechanical systems and maximize use of atmospheric conditions is greatly needed but is time consuming and difficult at best when done on an existing facility. Yet these may be accomplished via computer simulation with very good results. With this goal, the authors and other researchers at NCSU developed a numerical model of a storage room within an HVF. The incremental time model was developed to simulate the environmental conditions, control activity, and energy requirements during different sweetpotato curing and storage regimes and evaluate the effect of building design alternatives on these factors. The numerical model required input parameters such as: building specifications, climate data, quantity of sweetpotatoes, curing time and temperature, and storage temperature. Energy sources considered in the simulation included heat transfer between the building and surroundings and energy inputs due to mechanical devices, gas heaters, and sweetpotato respiration. Properties of the air during curing and storage were determined using psychrometric subroutines. Operation of heaters, humidifiers, fans, and vents was done according to a series of commands based on required frequency of operation and psychrometric conditions. The output of the computer simulation included sweetpotato and room temperature, control status, and energy consumption of the facility over time.

. It was found that the simulation generated good approximations of an HVF and showed great promise towards evaluating design alternatives. Limitations to the simulation were the user interface and need for additional output for the evaluation of control strategies. The current version of the simulation requires that the user has a working knowledge of FORTRAN programming, and thus is not suitable for distribution and widespread use.

b. Impact - It was found that the model generated good approximations of an HVF and showed great promise towards aiding in design evaluation. Limitations to the simulation were the user interface and need for additional output for the evaluation of control strategies. The simulation will provide useful insight into the energy requirements of existing and future postharvest storage facilities and allow for design modifications to be evaluated for effectiveness prior to new construction or implementing changes to existing buildings.

c. Source of Funds - Hatch, State

d. Scope of Impact - Regional

Key Theme - Food Quality

a. Determining parameters that affect particulate integrity during processing and developing correlations to predict the damage inflicted on particles would lead to enhancing the quality of thermally processed foods. This can be used by processors to design a process that will result in minimal damage. Studies were also conducted on residence time distribution of a mixture of particles during flow in different configurations of holding tubes. The effect of different process and system parameters on convective heat transfer coefficient in helical heat exchangers was determined. Studies also explored the possibility of using radio frequency to process liquid and particulate foods uniformly. Several mathematical modeling studies have been conducted to understand the various phenomena involved during flow and transfer of heat in helical systems.

b. Impact - The correlation developed on minimizing damage to particulates can be used by processors to design their process. Results of the studies on residence time distribution of particles in holding tubes will lay the foundation for the design of holding tubes for different applications. Predicting convective heat transfer coefficient as a function of process variables in helical heat exchangers will aid processors in optimizing their process to yield a product of high quality. The mathematical modeling studies have laid a strong foundation for design of holding tube sand heat exchangers that will result in the production of high quality foods.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Food Safety

a. As consumers become more aware of food-safety issues, producers are challenged to find new ways of ensuring that their food products are the safest, highest quality that money can buy. Cooling eggs quickly after they are laid is one way to ensure quality and a longer shelf life. But with traditional refrigeration methods, it can take seven to 10 days to reduce the internal temperature of eggs to 45 degrees F., the optimal temperature required by the U. S. Department of Agriculture. Researchers at North Carolina State University have developed a method of cooling eggs cryogenically that dramatically reduces the time needed to lower their temperature. Eggs are graded, washed and placed in cartons, then pass through a 15-foot cooler in 90 seconds. The cooler is filled with carbon dioxide gas at a constant temperature of minus 60 to minus 90 degrees F. The process reduces the cooling time for eggs from days to a matter of minutes.

b. Impact - By rapidly cooling eggs, producers can further reduce consumer's risk of contracting *salmonella enteritidis* from eggs. In addition, the process increases the shelf life of eggs from 30 to 60 days, increasing opportunities for exporting eggs and reducing producers refrigeration costs while enhancing overall egg quality. The process is commercially available to producers.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Foodborne Illness

a. Fresh eggs can be contaminated with Salmonella enteritidis, a microorganism proven to sicken people. Researchers at NCSU have developed a low-temperature, long-time water immersion heat treatment that produces salmonella free eggs.

b. Impact - Salmonella-free eggs may be used to make safe soft-boiled, soft-poached or sunny side-up fried eggs. Such pasteurized eggs may also be used safely in custards, Caesar salad dressing, ice cream, eggnog and sauces such as hollandaise sauce. Eggs processed using this technology were first test marketed in 1996. Michael Foods of Minneapolis is now using the technology in a Nebraska egg processing plant, which has an annual production capacity of 2.5 million dozen eggs. Eggs from this plant are being sold in Minnesota, South Dakota and Wisconsin. Based on the original research done at North Carolina State University, the egg pasteurization process received official FDA approval April 1, 1999. The process was noted in a report produced by the President's Council on Food Safety (Egg Safety Action Plan) as a viable processing option for assuring the safety of eggs. Additional marketing opportunities for pasteurized eggs are anticipated in the near future pending the approval of the product by two fast food chains. On the international front, Michael Foods is seeking to establish a joint venture with a European Union egg producer and processor to begin marketing pasteurized eggs to a major European Union supermarket chain.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Foodborne Pathogen Protection

a. The identification of new food safety strategies to combat bacterial pathogens on poultry products has been a priority of both and state governments, regulatory agencies, and food scientists over the last ten years. One particularly novel food safety strategy recently developed at North Carolina State University is active packaging materials (i.e., polymer and food-grade films, absorbent drip pads) containing food-grade bacterial inhibitors. In these studies, three common food packaging films having varying physical, chemical, and functional properties (nylon, polypropylene, linear low density polyethylene) were coated with a surface treatment containing several components including the natural inhibitor nisin, a protein produced by a common dairy fermentation organism (*Lactococcus lactis*). When applied to fresh poultry skin containing the bacterial pathogen *Salmonella* Typhimurium, the treated film yielded a significant reduction in the *S.* Typhimurium population of greater than 99.9%. When combined with an initial dip

treatment containing the nisin formulation, the treated films extended product shelflife by as much as two days. In related studies, inhibitory films produced from common edible proteins (agar) and carbohydrates (calcium alginate) produced similar lethal effects against *S.* Typhimurium when applied to contaminated broiler drumstick skin.

b. Impact - The exclusion of pathogenic and spoilage microorganisms from poultry products using unique approaches such as active packaging containing naturally occurring preservatives has an added advantage in that it provides a final safety hurdle for controlling undesirable organisms on poultry products throughout the wholesale and retail storage and distribution chain.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - HACCP

a. The Hazard Analysis and Critical Control Point (HACCP) regulations have created many challenges for the poultry industry. The implementation of the HACCP regulations have drastically increased the cost of operation for these processing plants. Even after making major investments there is still a need to further reduce pathogens on poultry. NCSU has develop and test in four locations an on-farm HACCP training program. At the four meetings participants from almost every poultry integrator in the state were given an overview of the training program and asked if they would be interested in personnel from their companies attending a more in-depth training. The participants in all four meetings indicated an interest in having the more in-depth training. The in-depth training programs are scheduled to begin in 2001.

b. Impact - Participants gained better understanding of how HACCP works in processing plants and how it could be applied to production operations.

c. Source of Funds - Hatch, State and Smith-Lever

d. Scope of Impact - National

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$319,244	$1,997,133	$675,725	$675,204	12.4	30.7	10.3	10.9

National Goal 3:
A Healthy, Well-Nourished Population

Program Area 8:
Human Nutrition and Human Health

Overview

Research activities in this program area have concentrated on improving human health through hazard reduction research and nutrition related to food choices, habits and consumption. Focus has been on food safety issues as related to overall consumer health and well-being. Some highlights of accomplishments in this program area are listed below.

- The rate of diabetes in the Eastern Band of the Cherokee Indians is over 30%. Several parameters measured indicate lower membrane fluidity of red blood cell plasma membranes and lower RBC deformability in some races relative to Caucasians. These differences may indicate a racial factor in the cause of insulin resistance and the etiology of diabetes.
- La Crosse virsus (LACV), a California serogroup bunyavirus, is the leading cause of pediatric arboviral encephalities in the United States and an emerging disease in Tennessee, West Virginia, and North Carolina. This discovery of LACV in wild populations of Aedes albopictus coupled with its expanding distribution in the Southeastern United States raises the possibility that this mosquito may become an important accessory vector, potentially increasing the number of human cases in endemic foci or expanding the range of the disease.
- Research studies show that fruits and vegetables contain antioxidants that can reduce free radicals associated with degenerative diseases. Work continues on determining processing effects on the antioxidant content and in development of a nutrient database for NC fruits for consumers.
- Limb development has been examined as a model for normal development. This model system has relevance to the induction of xenobiotically-induced (x-i) dysmorphogenesis. Additionally, x-i abnormal reproductive capacity and ability to transfer abnormal epigenetic-DNA status to future generations can now be studies. It is envisioned that findings will lead to the development of mechanically-based biomarkers of exposure which would be useful in detecting effects generated by endocrine-disrupting xenobiotics and texatogens.
- It is known that human liver microsomes metabolize chlorpyrifos to the potent anticholinesterase inhibitor, chlorpyrifos oxon, and to the detoxication product, 3, 5, 6-trichloropyridinol. Using this knowledge, a method has been developed for identification of individuals and populations at increased risk from organophosphorus insecticide poisoning.
- Studies examined selected pesticides in North Carolina surface waters that enter public drinking water supplies. This knowledge has led to agreements between city water specialists, farmers, extension agents, and university personnel resulting in pesticide reduction entering surface waters and ultimately getting into public drinking water supplies.
- Degenerative joint disease is a debilitating condition that results in the breakdown and wearing away of the articular cartilage that covers the bony surfaces of a joint. While this condition represents a significant health problem, very little is known about what factors initiate the breakdown of cartilage tissue or how the disease process progresses. Work is focused on early tissue changes that result in cartilage degeneration and, in particular, how loading might be influencing these changes.
- The German cockroach is a major urban pest worldwide that can acquire, carry, and transfer pathogens. Lipophorin involvement in hydrocarbon transport in this cockroach has been documented. Cuticular hydrocarbons are proving to be useful for the development of specific control technologies.

Key Theme - Health Care

a. Risk assessment is an important step in heart-disease management. For years, physicians have monitored blood cholesterol levels to assess risk of coronary heart disease. They measure patients' total cholesterol

and the amount of cholesterol in the high-density lipoproteins (HDL) and low-density lipoproteins (LDL). The problem is that HDL and LDL consist of several subclasses that differ in their associations with coronary heart disease. People with the same cholesterol levels but different lipoprotein subclass distributions can have very different heart-disease risks. Until now, doctors could not apply this knowledge because they lacked efficient, inexpensive laboratory methods to measure these subclasses. A scientist in the College of Agriculture and Life Sciences at North Carolina State University has devised a method using nuclear magnetic resonance technology to measure human blood lipoproteins. The method is the first to allow direct simultaneous measurement of the various lipoprotein particles that determine heart disease and produce a complete blood lipoprotein profile (NMR LipoProfile) in less than a minute, automatically. Clinical studies have demonstrated that the subclass information significantly enhances the prediction of coronary heart disease compared to the standard cholesterol risk factors.

b. Impact - This NMR test measures diagnostically-important information in less than a minute that previously required days of laborious testing in specialized lipid laboratories. This medical advance is expected to save lives by allowing physicians to identify earlier people at high risk of developing coronary heart disease. The test also has the potential to guide physicians to more cost-effective therapies on the basis of the patient's particular lipid metabolic condition, as reflected in the NMR LipoProfile. Commercialization of the technology has made NMR Lipoprofile testing available to physicians nationally, enabling improved clinical decision making about diet, exercise and drug therapy.

c. Source of Funds - Hatch, State and National Institute of Health

d. Scope of Impact - National

Key Theme - Human Health

a. Ovarian cancer is a deadly disease that kills more women than all other gynecological cancers combined. Each year in the United states, 27,000 to 28,000 women are diagnosed with the disease, and 16,000 to 17,000 women die from it. Despite progress made in treating cancers, most women who contract ovarian cancer will die from it. The disease is not easily detected and is often discovered in an advanced stage. Researchers at North Carolina State University and Duke University have shown that egg-laying chickens may be used as a model for studying ovarian cancer. Ovarian cancer occurs naturally at a high rate in chickens. The epithelial, or surface, cells of chicken ovaries are similar to the epithelial cells of human ovaries and appear to respond to the hormone progestin in the same way as human cells.
b. Impact - Chickens are playing a role in medical research aimed at developing therapies for preventing a deadly human cancer and saving lives. Chickens have been used, for example, in research designed to evaluate the use of progestins, compounds like those found in birth control pills, and caloric restriction, to prevent ovarian cancer. Both methods were found to be effective in reducing the incidence of cancer.

c. Sources of Funds - Hatch, State, Department of Defense, The National Cancer Institute, National Institutes of Health

d. Scope of Impact - International

Key Theme - Nutricueticals

a. Probiotics are microbial cultures that are considered to provide a variety of health benefits, including immune system stimulation, maintaining the proper microbial balance in the gastrointestinal tract, limiting antibiotic-associated diarrhea, cancer retardation, antagonism to enteric pathogens, and reduction of lactose intolerance symptoms. The predominant group of microorganisms considered to elicit these probiotic properties are members of the lactic acid bacteria, most notably species of *Lactobacillus* and *Bifidobacterium.* There is now considerable national and international demand for probiotic cultures that can be produced, stored and delivered through functional foods. Clinical evidence supporting the beneficial roles of probiotic cultures is slowly accumulating but has thus far failed to identify the specific properties that are responsible for cause and effect relationships. Researchers at NCSU are collaborating with scientists at California Polytechnic State University to sequence the genome of *Lactobacillus acidophilus* NCFM, the probiotic culture used in Sweet Acidophilus Milk. Sweet Acidophilus Milk contains high levels of *Lactobacillus acidophilus* NCFM, a culture that offers consumers the potential benefits of improving intestinal health, aiding digestion and stimulating the immune system. Many other lactic acid bacteria considered to have probiotic properties are being sequenced in a collaborative national effort. DNA sequences generated are being analyzed at NCSU for their functional properties.

b. Impact - Thus far, the project has identified a series of genes vital to the survival of probiotic cultures as they travel from food to the gastrointestinal tract. Efforts have increased the expression of genes that evoke tolerance to stress, resulting in probiotic cultures that are more resistant to acid, hot and cold temperatures, and oxygen stress. The project will identify genes that are vital to probiotic functionality and performance such that effective probiotic cultures can be delivered through a variety of food vehicles. Genomic efforts directed toward the lactic acid bacteria are revealing the mechanisms through which these organisms preserve our food, colonize our gastrointestinal tract, and evoke some important benefits to general health and well being.

c. Sources of Funds - Hatch, State

d. Scope of Impact - National

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$257,981	$1,176,856	$383,672	$93,489	8.0	14.1	8.8	6.6

National Goal 4:
An Agricultural System Which Protects Natural Resources and the Environment

Program Area 9:
Soil, Water and Air Quality Conservation and Management

Overview

The activities in this program area have been aimed at enhancing our understanding of the physical, biological and chemical processes and interactions influencing agricultural and forest ecosystem productivity. The interdisciplinary research projects will advance knowledge of natural processes to enable development of production management and environmental protection technologies that will enhance productivity; improve input efficiency; conserve natural resources; and improve and protect environmental quality. Some highlights of accomplishments in this program area are listed below.

- Water control structures using an orifice-weir improved water conservation and quality over free drainage.
- Evaluation of created tidal marshes established nearly 30 years ago showed good development of surface soil structure and organic matter (0-10 cm). Few changes have occurred below 10 cm.
- Studies of water flow from septic leach fields showed that water moved away from trenches through large cracks and macropores. Saturated water flow models verified the field results.
- A simple system of estimating the frequency and duration of soil saturation by assessing the abundance of gray soil color for a given depth was developed. The system estimates the likelihood that a soil will become waterlogged, which is important for delineating wetlands.
- Soil management studies with tomatoes showed that conservation tillage systems with synthetic fertilizers and pesticides resulted in greater tomato yield than conventional tillage systems on organic nutrients.
- Evaluation of alternative swine waste management technologies continued. Nitrogen in the waste was reduced by 90% with an anaerobic digester equipped with intermittent aeration.
- Fungi (Aspergillus niger) treated swine waste resulted in 90% reduction in Cu and Zn.
- Technologies are being evaluated for converting animal waste into marketable products. Manures and mortality products were successfully incorporated into animal feedstuffs.
- Efficient duckweed strains were identified that will maximize removal of N and P from lagoon wastewater. Duckweed harvesting systems were evaluated.
- Anaerobically treated swine wastewater was evaluated for use in greenhouse tomato production. Conversion of ammonium to nitrate is needed to optimize tomato yield. Substantial ammonium conversion was accomplished through biofilter facilitated nitrification.
- Applications of anaerobic swine lagoon effluent to corn and soybean resulted in 12% losses of applied N by denitrification.
- A project was initiated to evaluate the use of lagoon effluent as a fertilizer for the production of high value greenhouse crops. As such it will utilize recovered nutrients, waste heat and carbon dioxide to produce greenhouse vegetables.
- A new method of incorporating effects of odorous dust in odor measurements was developed. The method utilizing a cotton filter reduced both dust and odor in swine buildings.
- Sturdy, low cost windbreaks using steel conduit and ultraviolet resistant tarp materials reduced odor around swine buildings.

- Nitric oxide flux from intensively managed crop lands was measured. Flux increased with temperature when soil moisture was adequate.
- Ammonia emissions from areas near swine lagoons were measured. Higher emissions were observed in densely populated (hogs) regions compared to lower density areas.
- The introduced insect-parasitic nematode, Steinernema riobrave, was able to persist for two seasons after introduction into corn plots in eastern NC, demonstrating its strong potential as an alternative to pesticides against soilborne insect pests.
- Drought resistance was investigated by developing methodologies to effectively quantify Al tolerance in soybean, pine, kudzu, and velvetleaf.
- Regulation of nitrate acquisition and transport across plant cell membranes was investigated demonstrating changes in meristems cell division when plants enter phosphorus and nitrogen stresses.
- Developed and testing an automatic variable depth tillage system based on field maps of hardpan depth.
- Ozone phytotoxicity in plants was significantly reduced by elevated CO_2 concentrations.
- Using XANES spectroscopy, trivalent chromium (Cr) was present in Cr contaminated sites instead of Cr(VI), which is more environmentally toxic.
- Pasture ecology and grazing management research is helping farmers to reduce production costs by 20 to 50% without concomitant reductions to animal output.
- Grazing and metabolism studies with native grasses were conducted to determine animal efficiency and for reduction of pollution and habitat restoration.
- Active allelopathic agents in rye are being investigated, with emphasis on glucoside extracts.
- Use of cotton petiole K to assess K nutrition status did not prove useful in these initial studies. Addition trials will be conducted.
- P decision support system was developed to diagnose P deficiency and predict fertilizer P requirements.
- Optimum Irish potato yields were obtained with about half the recommended N rate.
- Nitrogen fate in turfgrass was investigated on golf fairways and data indicated that relatively small amounts of nitratie moves off site and riparian zones planted to grasses are effective at removing nitrate from shallow groundwater efficiency in turf.,
- Implemented variable rate technology for pesticide application.
- Developing methodology to selectively apply pesticides and growth regulators with electronic sensory equipment.
- Developed reference database for stable stream channel geometry in Piedmont and Mountains to assist in stream restoration design.
- Documented stream water quality improvements resulting from riparian buffer establishment on a Piedmont dairy farm.
- Riparian buffers used in conjunction with controlled drainage to reduce N loss to surface and ground water was evaluated.
- Development of a user-friendly computer interface program for vegetative filter strips (VFSMOD) continued. VFSMOD is a design tool for evaluating the effectiveness of vegetative filter strips for reducing offsite sediment losses.
- A Sediment and Erosion Control Research and Education Facility (SECREF) was established. The site is currently being used to evaluate technologies that reduce soil erosion at construction sites.
- Soil contaminant-mineral associations were assessed at several locations. Heavy metals (Zn, Pb, Cu) were enriched in the more dense particle size fractions and a strong association with Fe oxide minerals.

- Crop and weed responses to temperature and nutrition were investigated to define factors that control competition. Results indicated that some problem weed species have higher temperature optima than soybean, which explains the intensity of weed pressure during mid-summer.
- A long-term cropping system study was competed designed to evaluate rotational sequences for 10 peanut-based cropping systems. Results continue to suggest that yield is depressed in reduced tillage systems in most environments as compared to conventional tillage systems in peanut.
- Systems experiments were developed with different crops and monitoring methods to estimate economic thresholds in several agro-ecosystems, forestry, and successional ecosystems.
- Documented watershed-scale improvements in water quality resulting from BMP implementation on dairy farms in Long Creek (Gaston Co.)
- The ANSWERS model is being revised to evaluate watershed management impacts on water quality. Paired watersheds will be utilized to provide information on the long term efficacy of BMPs.
- Effects of waste lagoons on groundwater quality were continued. Approximately one-third of the lagoons showed elevated (> 10 mg/l) N concentrations in shallow groundwater. The N plumes do not appear to be expanding with time.
- Studies were initiated to evaluate the effects of subsurface drain depths on N losses to surface waters. Field sites were fully instrumented and data collection was initiated.
- DRAINMOD was utilized to assess water quality at the watershed scale (<10000ha). Model simulations were in good agreement with USGS monitoring data.
- The contribution of organic N mineralization to leachable inorganic N in turfgrass systems was evaluated. Results show little excess N available for nitrification and leaching.
- Extensive groundwater sampled under managed turf (golf fairways) showed very low nitrate concentrations compared to row crop systems.
- Earthworm castings (from solid animal waste) were evaluated as a soil amendment. Results showed reduced solids and nutrients in surface water runoff.

Key Theme - Agricultural Waste Management

a. Traditional animal waste treatment methods in North Carolina and the nation are under considerable criticism. In North Carolina, there is a regulatory effort to convert existing swine waste treatment technology -- the lagoon and spray-field system is used by most North Carolina swine growers to treat waste -- to alternative technologies. If alternative technologies are not well-researched, there is a danger that growers will be forced to convert to waste management systems that perform no better and perhaps worse than the system they now use. At the same time, conversion can be an expensive proposition, so conversion without adequate knowledge of system performance could endanger North Carolina's swine industry, which is worth as much as $2 billion annually to the state. Researchers and extension specialists at North Carolina State University have identified five promising alternative swine waste management technologies and are beginning to evaluate and demonstrate these technologies. Full-scale demonstrations of two of these technologies -- an in-ground anaerobic digester and a constructed wetland -- are in place on North Carolina farms, while full-scale demonstrations of other technologies are to begin in the near future.

b. Impact - This program is giving producers, policy makers and other North Carolinians the kind of information, including the associated costs and advantages and disadvantages of various waste treatment technologies, they need to make informed decisions regarding the implementation of new animal waste management practices.

c. Sources of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Agricultural Waste Management

a. Animal waste lagoons are potential sources of groundwater contamination. However, the actual performance of these structures, which play an integral role in the $2 billion a year swine industry in North Carolina, was not known well enough to make policy decisions regarding monitoring or remediation. A researcher from NCSU monitored groundwater in the vicinity of 34 North Carolina lagoons used to treat swine waste. Groundwater was monitored at locations 125 feet and 250 feet from the lagoons, all of which were built prior to 1993. The study showed that in most cases, there is little cause for concern for groundwater contamination from waste leaking from lagoons. However, where wells are located within 1,000 feet of a lagoon in the down-gradient direction, testing is advised.

b. Impact - This study provided much-needed data. This data may be used by policy makers to make science-based decisions that should improve environmental protection while avoiding unnecessary costs to producers and society.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Air Quality

a. Odor can be a problem for swine farms, and swine buildings can be a major odor source; the ventilation airflow needed to provide a good indoor environment carries odorous gases and dust out of the buildings. Engineers and scientists in the College of Agriculture and Life Sciences at NCSU have shown that devices called windbreak walls can modify odorous dust emissions from swine buildings without challenging existing ventilation systems. The walls are placed downwind of swine building ventilation fans, where they deflect fan airflow upward, improving mixing and dilution of fan airflow with wind passing over the building. Two low-cost windbreak walls designed to be erected on swine farms have been developed at NCSU. One makes use of ultraviolet-resistant plastic or tarps fastened to frames made from steel pipe, which is fastened to the ground. The second employs UV-resistant plastic or aluminum roofing fastened to treated lumber posts.

b. Impact - Swine producers have installed windbreak wall systems in North Carolina and other states. Consulting firms and equipment manufacturers are now designing and building windbreak walls for livestock producer clients, especially in states with new regulations, such as North Carolina and Colorado. The walls also give producers a viable option when they are legally required to institute odor control measures, as has been the case in North Dakota and Missouri. Windbreak walls are typically viewed by producers as a method they can employ quickly at limited costs.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Biological Control

a. Reducing the pesticide load in the environment is among the goals of the U.S. Environmental Protection Agency. Planting Bt transgenic cotton (cotton that expresses a toxin in the plant tissue) reduces the need to spray insecticide on cotton. Cotton farmers are able to plant a large proportion of their acreage in Bt cotton. However, corn farmers in the Cotton Belt, including North Carolina, have been restricted by EPA to planting 5 percent of their acres in Bt transgenic corn hybrids that contain the Bt toxin in corn ears. These corn hybrids provide superior control of several caterpillar pests. However, EPA has been concerned about the potential for the corn earworm, *Helicoverpa zea* (also known as the cotton bollworm), to develop resistance to the Bt toxin should a large amount of Bt corn be planted. Consequently, EPA chose a cautious approach and restricted Bt corn deployment until a science-based assessment of the role that Bt corn plays in hastening bollworm resistance to Bt cotton and strategy for managing resistance were available. Corn growers in North Carolina and elsewhere would like to be able to plant ear- expressing Bt corn, but do not wish to cause problems for cotton growers or want to abuse this powerful new insect control resource.

   Faculty in the College of Agriculture and Life Sciences at North Carolina State University have provided leadership in describing the relationship between Bt corn and Bt cotton in regard to resistance development in cotton bollworm (corn earworm) to the Bt toxin. Field, greenhouse, and laboratory research was conducted on the relative bollworm mortality, growth rate of surviving caterpillars, egg laying of surviving moths, and other parameters when the insects were infesting Bt and non-Bt corn hybrids. These and other data found in the scientific literature were used to develop a wide-area stochastic computer simulation model of resistance development in cotton bollworm populations within a virtual corn, cotton and wild plant environment. The computer simulation model described resistance emergence patterns in bollworm if different percentages of Bt corn and Bt cotton were planted. Also, the spatial pattern of Bt and non-Bt corn and cotton was varied across the landscape and observed for effect on resistance development patterns. The relative importance of each of approximately 25 factors was studied for impact on the resistance development process. These simulations provided an improved understanding of Bt resistance development in bollworm and relationships between Bt corn and Bt cotton. The model indicated that planting ear-expressing Bt corn was important to Bt resistance development in bollworm, but that Bt corn could be planted at a moderate to high percentage depending on the amount of Bt cotton planted. This provided EPA with science-based support for decision making.

b. Impact - In early 1999 EPA announced that ear-expressing Bt corn could be grown on up to 50 percent of the acreage in the Cotton Belt, including North Carolina. The project served as a model for how insect resistance management issues relating to transgenic crops in a multiple crop system may be addressed by scientists, EPA, corporations and growers. Bt transgenic plants represent a valuable resource for managing insects and reducing insecticide in the environment. Science-based decisions provide the best hope for preserving this technology and assuring a long and useful life for this pest-management technology.

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Hazardous Materials

a. In the United States, there are thousands of sites that are contaminated with potentially toxic substances such as heavy metals and organic pollutants. Because of the potential health risks of these sites, site cleanup is a major issue. The projected cost of cleaning up all hazardous waste sites in the US is in the hundreds of billions of dollars. In North Carolina alone, there are hundreds of sites that are contaminated with heavy metals. The average cost of cleaning up these sites ranges from $150,000 to $250,000 per acre, with sites ranging in size from 2/10 acre to a hundred acres. Research provides a scientific basis for prioritizing heavy metal contaminated sites for cleanup based on the potential threat of contaminants. In some cases, the metals are bound so strongly with soil particles that they can effectively be considered inert, at least in the short term. However, it is not yet understood how the interactions between metals and soils well enough to project when a contaminated site poses a health threat or not, particularly in the long term. Certain forms of heavy metal contaminants in soils are less hazardous than others. Advanced techniques to determine whether the form of metal in a particular soil will be hazardous or not. In the past, data has been used to support remediation options that allow the contaminant to be managed in a soil without removing it. This approach is much less costly than digging up the contaminated soil and moving it to a hazardous waste dump, and the cost savings can be transferred to cleaning up more hazardous sites. In specific research on metal-contaminated soils from sites associated with the Marine Corp Air Station in Cherry Point, North Carolina, we determined that chromium and arsenic in the soils were in their less toxic forms. This information along with our measurements of total metal concentrations will be useful for determining safe, yet cost-effective remediation options for these sites.

b. Impact - The potential impact of the research to the US Marine Corps is a cost savings of hundreds of thousands of dollars if the metal contaminants at the sites can be managed in place to minimize their environmental impacts.
c. Sources of Funds - Hatch, State

d. Scope of Impact - National

Key Theme - Integrated Pest Management

a. North Carolina apple growers must find alternatives to the organophosphate insecticides they have relied on for more than 30 years to protect their crops. It appears likely that government regulatory action will reduce the availability of organophosphate insecticides, and buyers of processing apples are concerned about pesticide residues on apples. Gerber Products Company, a major buyer of apples in North Carolina, informed growers in November 1999 that the company would not purchase apples treated with organophosphate insecticides beginning in 2000. Research and extension programs at North Carolina State University focused on biorational methods of insect control. Methods include pheromone-mediated mating disruption and new pesticides that must be used in an entirely different manner than the insecticides growers have been using. On-farm research demonstrated that new technology can be used to significantly reduce the use of organophosphate insecticides. A partnership between NC State University, the North Carolina Apple Growers, the pesticide industry, and Gerber was formed to oversee the successful implementation of a reduced-risk management approach on 1,000 acres of North Carolina apples in 2000. With the aid of a USDA Pest Management Alternatives Program grant, the project will be expanded to include additional processing and fresh market growers in 2001.

b. Impact - The successful implementation of this program has allowed North Carolina apple growers to maintain a critical market for processing apples and enabled them to remain competitive on national and state markets.

c. Source of Funds - Hatch, State and Smith-Lever

d. Scope of Impact - Regional

Key Theme - Nutrient Management

a. Improper nutrient management wastes money and can lead to water pollution. Improper use of plant nutrients can result in an economic loss to farmers and land managers. Poor nutrient management can also result in significant impacts on water quality. The effects of nutrient application on water quality have been measured in a variety of experiments. Golf course fertilization does not appear to have a significant negative effect on groundwater quality. Applications of phosphorus fertilizers are less prone to runoff during storms if they are plowed into the soil. However, plowing increases the total amount of sediment lost and total erosion. Swine manure makes an excellent source of plant nutrients when properly managed and applied to crops. It is also possible to remove a large proportion of the nutrients from the swine liquid by letting it precipitate into a solid (struvite) prior to pumping the liquid to the growing crop.

b. Impact - Management recommendations are being revised to allow nutrient users to utilize this resource more carefully. This will result in economic savings and potential water quality benefits.

c. Source of Funds - Hatch, State and EPA

d. Scope of Impact - Regional

Key Theme - Pesticide Application

a. Tomato foliar diseases have long been an important limiting factor to North Carolina's $20 million fresh market tomato industry. In the past, tomato growers sprayed their crops with protectant fungicides every 4 to 5 days to prevent diseases such as early blight, late blight and Septoria leaf spot. Without fungicide applications, diseases can cut the value of tomato crops in half. But protecting tomatoes meant spraying them with fungicides as many as 25 times during the growing season. NCSU researchers and extension specialists located at the Mountain Horticultural Crops Research and Extension Center at Fletcher have been searching for ways to reduce the heavy use of fungicides on tomatoes on two fronts. New fungicide chemistries that provide better control of tomato foliar disease have been evaluated while plant breeders are working to develop new tomato varieties with multiple disease resistance that require less fungicide to produce healthy crops. One new fungicide in particular has been shown to improve disease control, especially of early blight, and spray schedule strategies were developed that integrated this fungicide with other fungicide materials, allowing applications at 7-10 day intervals. Considerable progress has also been made in developing new varieties that combine high levels of late blight resistance from wild tomato species with existing early-blight-resistant tomato varieties.

b. Impact - This research has already reduced total fungicide usage by North Carolina tomato growers by at least 25 percent. With the introduction of future multiple disease-resistant tomato varieties, fungicide usage can be expected to be reduced by more than 50 percent.

c. Source of Funds - Hatch, State and Smith-Lever

d. Scope of Impact - Regional

Key Theme - Riparian Management

a. Riparian buffers -- strips of vegetation -- have been shown to be an effective method of reducing erosion, which is a major source of pollution in surface waters such as streams, rivers, ponds and lakes. Yet it can be difficult to determine the optimum size of a riparian buffer. Researchers at North Carolina State University are developing engineering design tools to help water quality agencies optimize buffer size. Among these tools is a computer model, called VFSMOD, that simulates how effectively vegetative filter strips trap sediment.

b. Impact - VFSMOD gives water quality regulators the ability to size vegetative buffers and evaluate their effectiveness reducing sediment transport to surface waters over a range of soil types.

c. Source of Funds - Hatch, State

d. Scope of Impact - Regional

Key Theme - Soil Erosion

a. Farmers in North Carolina face increasing challenges. Crop prices have been unusually low, and the long-standing farm programs that have helped keep the profit potential in tobacco and peanuts are rapidly being dismantled. The damages from hurricanes in 1999 resulted in poor yields from many of the fields that

could still be harvested. If farmers are growing crops like cotton, corn and soybeans, this must be done with maximum attention to efficiency and profit potential. Profit starts with good yields and by minimizing costs. Drought stress is a factor that generally limits crop yields more than growers realize. Successful conservation tillage in the form known as "strip tillage" can improve yields and allow growers to become more efficient by reducing time and equipment labor in the preparation and planting of each acre. Often this has allowed farmers to operate more acres, thereby squeezing more efficiency from their existing equipment capacity. There are new products being aggressively marketed to farmers, and decisions about what products to buy can be difficult for farmers. Faculty with North Carolina State University are studying agricultural productivity and conservation tillage. They have compared various tillage approaches, and continue to test some of the new items being marketed. During 1999 they conducted a field study comparing three current forms of deep tillage that could be used to correct soil compaction under conservation tillage management. They chose a field where the "pan layer" problem was present, and in cooperation with the farmer and local Extension agents, evaluated the effectiveness of the tillage equipment. They also examined the rooting pattern and growth of the cotton.

b. Impact - This project helped in determining that all of the tools improved the depth of rooting of the cotton plants, but one brand of equipment seemed to leave an undesirable cavity in the soil. The extension team used this information in discussions and meetings with farmers to help the farmers make informed decisions that will lead to greater productivity. Helping farmers make equipment choices wisely will encourage adoption of successful and more profitable conservation tillage production. At the same time, this will bring environmental benefits in the form of reduced erosion. Also, if there is increased use of small grain cover crops with good management of these cover crops, especially for cotton production, there may be some reduction of nitrogen moving toward groundwater. This is becoming a matter of increased concern as we look for means of reducing nutrient contamination in our major river basins.

c. Source of Funds - Hatch, State and Smith-Lever

d. Scope of Impact - Regional

Key Theme - Soil Quality

a. One of the potential approaches to overcome the widespread soil acidity constraint to crop productivity is the identification and development of aluminum-tolerant cultivars. A cost-effective method to screen a large number of genotypes for aluminum tolerance is through the use of short-term hydroponic techniques. However, there are numerous hydroponic methods with different solution compositions and the collective results indicate variable rankings of aluminum tolerance among the same genotypes. NCSU faculty have investigated the role which various cations in hydroponic solutions have on variable rankings of soybean genotypes for aluminum tolerance. Differences in genotypic rankings among solutions were related to variable concentrations of magnesium. The effect of magnesium on modifying aluminum tolerance of genotypes for soybean was not observed when hydroponic screening was performed for wheat genotypes. This indicated that direct transferral of hydroponic screening techniques among crop species was not possible.

b. Impact - Improved understanding of the role of magnesium on differential tolerance to aluminum among soybean genotypes should improve the use of hydroponic methods in screening germplasm for identification and development of cultivars tolerant to acidity. Greater reliability in the initial screening of

germplasm in hydroponic tests will improve the cost-effectiveness of subsequent field testing and cultivar development based on the selection of promising materials.

c. Source of Funds - Hatch, State

d. Scope of Impact - Regional

Key Theme - Sustainable Agriculture

a. Different species of plant-parasitic nematodes (microscopic worms) attack almost all crops grown in NC and the world. Crop losses to nematode damage throughout the world are estimated to exceed $70 billion every year! For many years, toxic nematicides have been applied to soil to control these root pathogens, but environmental and cost concerns have severely restricted the use of these agrichemicals. Growers urgently need alternative strategies to reduce nematode damage to their crops. In some cases, natural sources (genes) for resistance to nematodes can be incorporated into crop cultivars by plant breeding. In many cases, unfortunately, natural sources of nematode resistance do not exist for many important crops and nematode species. In addition, some nematode races have evolved to overcome some natural sources of nematode resistance in available crop cultivars. Biotechnology, however, can provide novel ways to develop resistance to nematodes in desirable crop cultivars by specifically and safely interfering with the mechanisms that nematodes use to attack plants.

. A research program is active at NCSU to discover the mechanisms that nematodes use to attack plants at the molecular level. Research in the Department of Plant Pathology has made significant advances in understanding the mechanisms of parasitism by cyst nematodes that attack the roots of soybean and tobacco. For the first time anywhere in the world, the genes that these cyst nematodes use to produce molecules necessary for plant root parasitism are being cloned and identified. Already, a cyst nematode gene that allows the nematodes to degrade plant cell walls and penetrate plant roots has been identified. A genomics approach has been initiated that recently has discovered a panel of other nematode genes involved in plant parasitism that are now being analyzed. The next phase of this project has also been initiated: developing a way to specifically inhibit these nematode parasitism gene products to make bioengineered crop cultivars that are resistant to the nematodes. Not only is this feasible, but these strategies have the advantage of being targeted exclusively to damaging nematodes with no detrimental impact on food safety or the environment.

b. Impact - Soybean yield losses to cyst nematode damage in NC are estimated at $10-20 million each year, and close to $1 billion/year throughout the United States. Natural resistance to cyst nematodes has been incorporated into some soybean cultivars, but the nematodes have been able to adapt to and overcome these natural sources of resistance in the field. Tobacco represents a $1 billion/year crop in North Carolina, and the recent spread of the tobacco cyst nematode in NC is particularly menacing since no cyst nematode-resistant tobacco cultivars are available that growers will use. It has been estimated that a nematode-resistant cultivar can provide up to 400 times the return on an original research investment (ie. in reduced economic crop losses to nematode damage). Nematode-resistant cultivars developed through biotechnology can potentially match or exceed this estimated return on investment and have the added bonus of retaining the durability of the resistance for much longer periods of time than natural sources of resistance.

Key Theme - Water Quality

a. Nitrogen can move from farm fields, where it is a valuable fertilizer component, to groundwater and surface waters. In groundwater used for drinking, nitrogen in excessive amounts can pose a risk to human health. In surface waters, it can fuel fish-killing algal blooms. Nitrogen in surface waters is also suspected of being a stimulants of *Pfiesteria pisicida,* a poisonous dinoflagellate that is lethal to fish and believed toxic to recreational water users. North Carolina State University scientists developed a system known as

controlled drainage to decrease the amount of nutrients moving from farm fields to surface water. Farmers install a system of culverts and boards in ditches; using the system, they can release water when fields are wet yet retain some for drier times. North Carolina State University scientists have also shown that most fertilizer nitrogen not used by agricultural crops can be removed from groundwater by riparian buffers before it causes problems in surface waters.

b. Impact - Essentially all new methods and regulations for minimizing nutrient movement from agricultural land to surface water are based on North Carolina State University research. On farms with controlled drainage, about half the nitrogen previously lost to surface water is converted to nitrogen gas, which is absorbed harmlessly by the atmosphere. North Carolina has deemed the environmental benefits of the practice so great that the state shares with farmers the cost of installing the drainage structures. As a result, controlled drainage has been adopted on some 600,000 North Carolina acres, and the practice has spread to other states and countries as well. In North Carolina, increased corn and soybean yields that result from controlled drainage are worth $5 million annually. Recommendations for riparian buffers have been accepted by state regulators and are now a requirement under certain conditions in nutrient-sensitive North Carolina watersheds.

c. Source of Funds - Hatch, State

d. Scope of Impact - Regional

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$797,980	$4,392,913	$1,582,050	$1,067,006	24.3	38.9	37.7	14.5

Program Area 10:
Forest, Pasture, Wildlife and Fish Resource Conservation Management

Overview

Research activities in this program area have concentrated on understanding relationships between soil fertility and plant communities; identifying biological and physio-chemical factors that influence establishment and growth of trees; describing physiological mechanisms controlling reproductive biology of fish; developing improved understanding of the habitat factors that influence reproduction and survival of terrestrial wildlife; and identifying environmental factors that influence the reproduction, recruitment and survival of fish. Some highlights of accomplishments in this program area are listed below.

- Established research program to relate soil and site characteristics to nutrient management needs for maximum biological and economic productivity with minimal adverse environmental effects.
- Applied research programs in tree improvement were integrated with programs in forest biotechnology and wood quality to develop trees with faster growth rates and better fiber quality.
- Identified hormonal regulators, arginine vasotocin, of sexual behavior in striped bass and white perch.
- Elucidated the sexual differentiation schedule for southern and summer flounder, two species with potential for aquaculture.

- Cloned the gene for the enzyme that encodes aromatase, which appears to regulate female sexual differentiation. This is a first step in selecting genotypes that produce disproportionate numbers of faster growing females.
- Discovered that insulin growth factor I regulates the responsiveness of ovarian follicles to hormones and oocyte maturation in temperate basses.
- Developed a novel test involving reactions of ovarian biopsies to insulin growth factor I for identifying brood stock that is sufficiently mature for induced spawning.
- Discovered in 3 fish species a redundant system for egg yolk formation based on the yolk precursor protein vitellogenin.
- Identified the site on vitellogenin protein that binds to the oocyte receptor, which opens the possibility for delivery of bioactive materials into fish eggs and offspring.
- Documented that domesticated striped bass and white bass broodstock produce hybrid offspring with fertility rates and survival rates of progeny equivalent to those obtained with wild broodstock, which allows selective breeding of hybrid striped bass for commercial aquaculture.
- Studies of release of captively bred Dominican parrots have laid the foundation for the restoration program for the endangered Puerto Rican parrot.
- Developed GIS based habitat model to assess the significance of the Great Smoky Mountains National Park as a population source for the wood thrush.
- Assesses the significance of the old-growth Appalachian forests for threatened and endangered salamanders and songbirds.
- Developed GIS based habitat models to assess landscape scale effects of forest management on Appalachian songbird populations.
- Determined that a 350,000 acre managed industrial forest on the coastal plain is an important source of biodiversity for songbirds.
- Demonstrated that chronic exposure to sub-lethal low oxygen concentrations decreases growth of shrimp and juvenile estuarine fish and lowers disease resistance in fish.
- Demonstrated that distribution of pelagic fish in the Neuse River estuary is positively correlated with oxygen concentration.
- Developed and field validated a model that predicts accurately the growth of juvenile red drum as a function of food, temperature, oxygen concentration, pH and salinity.
- Demonstrated that variations in spring temperatures dictates year class strength and recruitment of largemouth bass by influencing duration of embryonic incubation.
- Showed that declines in water level of a tropical reservoir during spawning season of largemouth bass interrupt or terminate spawning and, thereby, reduce recruitment.
- Incorporated 13 years of field data into the development of a model that relates effects of land use and climate change to the dynamics of small mouth bass populations. This large scale approach elucidated processes that could not be understood by conventional approaches.
- Showed by radio tagging that striped bass and American shad use spawning habitat that was restored by removal of a low-head dam.
- Located spawning sites for the threatened Gulf sturgeon in the Choctawhatchee Rive in Florida and Alabama.
- Published a new model that describes dispersal and redistribution of riverine fish.

Key Theme - Endangered Species

a. Bobwhite quail and 17 other birds associated with grasslands and shrub habitats have been declining in farm lands of Eastern North Carolina and other Southeastern states at a rate of approximately 3 percent per year for more than three decades. Prevailing opinion among wildlife biologists is that habitat used by these animals has been lost due to greater intensification of row crop agriculture. Researchers at North Carolina State University are working to determine the reasons for this downward trend in farm wildlife and to develop cost-effective, environmentally beneficial methods of improving wildlife habitat and reversing the trend. This research has shown that while toxic in laboratory settings, modern pesticides properly applied in the field have minimal direct impact on quail health or reproduction. Indirect effects associated with clean farming -- creating crop fields devoid of all plants but the crop -- were a major cause of quail decline. In an effort to give farmers better information about wildlife and pesticides, eight crop-based fact sheets explaining the probable effect of various pesticides on wildlife were produced. Researchers showed that conservation tillage and vegetative field borders can be used to provide quail nesting and brood cover and increase quail populations. This work is continuing with a regional experiment designed to test habitat enhancement and predator management on farms in three agronomic regions.
. This research has shown that in North Carolina the suspicion that modern pesticides have caused the demise of farm land birds is probably false. It also appears unlikely, based on this research, that predators such as foxes, racoons, opossums and skunks are the principal cause of depressed quail populations. However, quail populations have doubled where field border systems have been installed, and it has been shown that no-till soybean and corn production provide excellent brood habitat for quail chicks. In addition, field borders hold three times more wintering sparrows than fields without borders. Field border systems also appear to harbor beneficial invertebrates such as spiders, and corn earworms, the most important cotton pest, are significantly reduced in crops near field borders. Furthermore, in clay-loam soils, field borders may reduce soil loss and nitrate movement into ground and surface waters. At the same time, this research indicates that farming edges of fields tends to be unprofitable due to yield drop-offs. A metal wick herbicide applicator for woody plant control was developed as part of this research effort. Using this machine, now in its second generation, cuts field edge maintenance costs by half.

b. Impact - This effort has shown that agriculture and wildlife can coexist. It has demonstrated and continues to demonstrate how the downward trend in quail and other farm land bird populations can be stemmed without economic damage to farmers.

c. Source of Funds - Hatch, State

d. Scope of Impact - Regional

Key Theme - Natural Resources Management

a. With a large agricultural sector and fast growing urban centers, nutrient pollution from non-point sources has become the state's primary water quality problem. Debate in NC has focused on the correct course of action concerning this. As is always the case with such debates the discussion of tradeoffs is involved. Water pollution prevention is costly. Upon whom should these costs fall? Are the costs worth it? This research focuses on the latter question, investigating means of determining the monetary value of water quality improvements. These values are largely non-market in nature. That is, one does not go to the store to purchase water quality. This, however, does not imply that improved water quality does not have value, or that individuals would not be willing to pay to have improved water quality. A descriptive list of the reasons individuals may hold value for water quality includes health reasons, the desire to leave clean

water for future generations, and the recreation benefits of clean water. This research focuses on the recreation benefits of water quality improvements. Data from two sources were compared. A survey conducted in 1994 by the U.S. Environmental Protection Agency provides information on water recreation activity in NC. Additional data from the EPA provides a summary of water quality conditions at watersheds throughout the state. Examining these data together showed individuals are willing to travel further, and hence pay larger travel costs, to visit recreation sites in watersheds with cleaner water. A formal econometric model based on this fact revealed that people are willing to pay more money out of their budgets, in terms of the implicit travel costs, for cleaner water. The method allows us to place a specific dollar value on improvements in water quality in areas throughout the state.

b. Impact - Among other things this model allows us to consider the monetary value of water quality improvements in the Neuse River basin. For example reductions in nutrient levels such that the river would support all recreation uses, including contact uses, are estimated to have a value per recreation trip between $0.18 and $1.23. Using a rough estimate of the number of water recreation trips made in the state in a given year this translates to approximately $10.4 million in annual recreation benefits for this improvement. This information is useful as policy makers and regulators attempt to determine the proper level of water quality regulation.

c. Source of Funds - Hatch, State

d. Scope of Impact - Regional

Key Theme - Wetlands Restoration and Protection

a. Wetlands are an essential element of the landscape, functioning to buffer storm runoff, improve water quality, and provide habitat for valuable wildlife and vegetation. Many wetland restoration efforts in North Carolina have failed to meet the restoration goals imposed by the US Army Corps of Engineers. Frequently, these failure result from multiple shortcomings in site assessment, identification of potential functions, methodologies to restore wetland functions, and effective assessment of the progress of functional restoration. Scientists in the Departments of Soil Science, Forestry, Biological and Agricultural Engineering, and Botany at North Carolina State University have begun utilizing and developing a variety of techniques to assess soil, hydrologic, and site parameters that affect wetland restoration success. The methods being used include conventional techniques traditionally used to assess soil characteristics, hydology, and vegetation. In addition, several relatively new remote sensing technologies are being evaluated for their potential to evaluate factors affecting restoration success and to monitor restoration progress.

b. Impact - When highway construction by the North Carolina Department of Transportation adversely affects wetlands that highways must cross, NCDOT is required to restore wetlands elsewhere. In addition, other local, state, and federal agencies, as well as conservation organizations and individuals, frequently seek to restore drained land to wetland status. The techniques developed in this project will improve our ability to: choose appropriate sites for wetland restoration, utilize appropriate methods to achieve that restoration, and monitor restoration progress.

c. Source of Funds - Hatch, State

d. Scope of Impact - State

Key Theme - Wetlands Restoration and Protection

a. Salt and brackish water tidal marshes provide food and habitat for marine organisms, improve water quality by removing sediment and nutrients and protect shorelines from erosion. More than 50 percent of the tidal marshes in the United States were lost due to dredging, filling, diking and levee construction. To replace marsh habitat that has been lost and to mitigate losses that may occur in the future due to activities such as road and bridge construction, there is an increased interest in restoration and creation of tidal marshes. Constructed wetlands technology is useful for improving water quality through filtering denitrification and other biogeochemical transformations. North Carolina State University, with support from Sea Grant, the U.S. Army Corps of Engineers, PCS Phosphate and the Environmental Protection Agency, has developed techniques for restoring and creating tidal marsh habitat. The marshes that are created using this technology have many of the values and functions of natural marshes. Research in progress has the goal of quantitatively comparing structure and function of created and restored marshes with natural reference marshes.

b. Impact - Successful tidal marsh restoration and creation has positive environmental and economic benefits. North Carolina State University faculty members have been directly involved in the creation of 20 to 25 acres of tidal marsh, while the restoration and creation techniques developed at NC State have been used by state agencies, individual landowners and corporations to create or restore many more acres. These projects have been implemented to stabilize dredged material, to restore and create wildlife habitat, to control shoreline erosion and as mitigation required by government regulations to compensate for destruction or impacts on natural stands. The ability to mitigate wetland impacts using creation and restoration techniques allows critical development such as bridge, highway and port construction to proceed without a net loss of valuable tidal marsh habitat. Constructed wetlands are a low-cost, environmentally sound technique for removing and transforming pollutants from water flowing from point and nonpoint sources. Continuing to develop this technology will improve water quality at a cost less than mechanical treatment systems.

c. Source of Funds - Hatch, State and Environmental Protection Agency

d. Scope of Impact - National

Key Theme - Wildlife Management

a. Research is being conducted to elucidate the mechanism of interaction of venomous animals and their prey in the context of coevolution. Species of natural prey (bullfrogs) of the cottonmouth are more resistant to venom than are species (e.g.., toads) that are not part of its diet. Bullfrogs extend beyond the geographic range of cottonmouths and in localities where cottonmouths are absent, frogs are less resistant to venom than are those from places where predator and prey coexit. Tadpoles are protected by toxic skin secretions and sensitive to snake venom. At metamorphosis they lose the protective skin glands and develop a resistance to snake venom.

b. Impact - The study venom is important because it sheds light on the evolution of anti-predator strategies of prey and their circumvention through counter adaptation by predators. Coevolution is a controversial topic. Studies thus far have demonstrated the reality of the phenomenon in venomous snakes and their prey.

c. Sources of Funding - Hatch, State

d. Scope of Impact - National

Key Theme - Wildlife Management

a. Largemouth bass are the principal sport fish of warm water reservoirs. Sustained quality fisheries depend on satisfactory annual recruitment, which in turn depends on successful annual hatches and productivity of young. Twelve years of research have been conducted in North Carolina and eight years in Puerto Rico, thereby facilitating comparison of recruitment mechanisms. Annual and spatial variability in abundance of young bass has been assessed and related to physical and biological factors.

b. Impact - Management agencies are considering adoption of water level stabilization policies to protect and enhance reproduction and juvenile survival; implementation of stocking and habitat management manipulations on localized scales where benefits will be maximized; and promulgation of harvest regulations to optimize productivity to the fishery.

c. Sources of Funds - Hatch, State

d. Scope of Impact - Regional

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$101,627	$1,507,148	$956,999	$519,433	7.4	26.1	9.6	4.2

National Goal 5:
Enhanced Economic Opportunity and Quality of Life for Americans

Program Area 11:
Individual, Family and Community Economic Development and Quality of Life

Overview

Activities during 2000 in this program area included studies on rural community change, children and youth at risk, community development and youth development. Some highlights of accomplishments in this program area are listed below.

- A study conducted by an Ag Economists suggests that the movement of people from rural counties, at least in North Carolina, could be more of a drain than a benefit to those rural areas. In 1990, 18 percent of workers in rural counties adjacent to urban centers traveled to those urban counties to work, compared to only 7 percent in 1960. The results seem to suggest that people move to get out of the city. Two factors that have facilitated the rural-to-urban commuting trend are better roads and greater affluence. These changes have both positive and negative impacts on rural areas. On the positive side, new residents bring new demands for services offered by grocery stores, restaurants, dry cleaners and the like. On the negative side, more people create more demand for expensive government services such as schools, trash collection, and water and sewer infrastructure.
- To understand the impact of industrialized hog production, a study was conducted by a rural sociologist that focused on hog producers, citizens, anti-hog activists, and local business leaders. A core theme that emerged was that rural life is based on being a "good neighbor" and on maintaining the sustainability of natural and agricultural resources. However, the social definitions and meanings of "good neighbor" and "sustainability" differed markedly among the groups. All groups looked to government to come up with specific solutions to the problems of waste and odor, and general solutions to redress allegations of unfairness and unequal protection. Questions of the sustainability of agriculture also involve questions about the nature of rural life, the economic transformation of rural communities, and political power.
- In a study conducted by a rural sociologist, hundreds of youth about workplace injuries. The results suggest that more than half of working teens hand suffered workplace injuries and two-thirds reported using dangerous or illegal equipment. Most of the youth perceived their jobs as dangerous, and yet nearly half had received no on-the-job training. On the basis of these results, a safety training program has been developed for teen workers. Additionally, others have used the results to inform policies and programs for injury surveillance and reduction of occupational injuries nationwide.
- A study by a rural sociologist attempts to document the extent of substance abuse problems and availability of treatment in rural as compared to urban counties. One of the major findings is that substance abuse clients commute over 40 miles for treatment, which may be done to preserve

anonymity as well as absence of treatment facilities. These results suggest that data from directors of programs and without patients residence of the may be misleading. For some counties the number of cases treated may lead to inflated estimates of substance abuse problems in that community or county.

- A rural sociologist has been involved in community capacity building, which is a systematic approach to assisting organizations to play a major part in the regeneration of their communities. Increasingly, community organizations are becoming involved in local partnerships, in the management of projects and services and in the creation of community enterprises. These organizations require help with training, organizational development and resources to enable them to have a full and lasting impact on community development.
- The southern Black Belt, which is the largest, poorest, and most rural region of the United States, is the focus of a research and outreach project to provide basic information and issue awareness, analytic scientific models for solutions to the region's problems, and meaningful policies and programs to change the longstanding course of the region.
- A program of research and dissemination of youth career information has been developed by a rural sociologist. Youth and Careers is a program that is designed to help young people make informed and responsible career decisions. This research focuses on critical career development issues by studying rural high school students to determine how parents influence their sons' and daughters' career plans.

Key Theme - Workforce Safety

a. The National Institute for Occupational Safety and Health (NIOSH) estimates that 64,000 teenage workers are treated for work-related injuries in hospital emergency departments annually and that more than 21,000 work-related injuries and illnesses suffered by teenagers result in lost work days each year. Scientists in the College of Agriculture and Life Sciences at North Carolina State University, working with researchers from the School of Public Health at the University of North Carolina at Chapel Hill interviewed hundreds of North Carolina youth people about workplace injuries. The researchers found that more than half of working teens had suffered workplace injuries and two-thirds reported using dangerous or illegal equipment. Most teenage workers perceived their jobs as dangerous, yet nearly half had received no on-the-job safety training.

b. Impact - Building on this research, groups in Massachusetts, California, West Virginia, Pennsylvania and North Carolina have developed safety training programs for teen workers, and others nationwide have used the results to inform policies and programs for injury surveillance and reduction of occupational injuries.

c. Sources of Funding - Hatch, State, National Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, National Institute for Occupational Safety and Health of the Centers for Disease Control and Prevention

d. Scope of Impact - National

Key Theme - Impact of Change on Rural Communities

a. Many NC counties report shortages in funding for public goods, such as school and road construction. Part of the reason may be the fact that real property, which serves as the base for a large percentage of county public revenues, is reassessed only every seven years. Even new real property is assessed at an

estimated value during the most recent reassessment. As a result, the real property economic base lags behind economic growth in any counties. Counties can increase the property tax rate between reassessments periods, but public resistance may prevent the rate from rising enough to keep property tax revenues growing with the general economy in the county. Hence, there may be automatic shortfalls in property tax revenues due to the lags in property tax reassessments, especially in fast-growing counties. Data were collected on assessed property values and property tax rates in all 100 North Carolina counties for each year from 1980 to1995. Data from the NC Association of County Commissioners were used to construct market values of real property in each year in each county. Property tax collections were compared from the current system to an alternative system of applying a fixed property tax rate to the market value of real property. It was found that the alternative system would yield an annual average of 10% greater property tax collections. This rate is higher in faster-growing counties. This suggests the current system does under fund public goods.

b. Impact - Local public officials can use this information to judge whether more frequent real property reassessments could help counties meet their demand for public goods. The alternative system would assess annually changing market values of real property at an unchanging property tax rate.

c. Source of Funds - Hatch and State

d. Scope of Impact - State

Key Theme - Workforce Preparation - Youth and Adult

a. The teaching of science in elementary and secondary schools has traditionally focused on student assimilation of factual information (scientific knowledge) and concepts (scientific principles). There is little or no emphasis on science as a process (scientific method). As a result, students enter college (often as science majors) with a false impression of what constitutes scientific inquiry. Many students struggle in freshman-level science courses because they have been trained to memorize facts instead of synthesizing and applying them. The North Carolina Department of Public Instruction has adopted a K-12 science curriculum that places greater emphasis on inquiry-based learning and science process skills. Many teachers are not familiar with this approach or view it with skepticism because they have never used it successfully. These teachers need support, guidance and model lesson plans to help them make the transition from knowledge-based instruction to discovery-based instruction. A scientist in the College of Agriculture and Life Sciences at North Carolina State University created a course called "Entomology for Educators" that is designed to give classroom teachers (and science education students) a stockpile of ideas, activities, resources and experiments for teaching fundamental topics in biology and ecology. The topics range from symbiosis to population genetics and from animal diversity to succession. Most topics involve the use of insects (or related arthropods), and all of them incorporate scientific methodology and help students develop critical thinking skills. The topics are designed to closely parallel the new K-12 science curriculum so teachers can see how each unit fits into the overall plan.

b. Impact - Marife Ortega won first place in a science project competition for her project on antimicrobial factors in the blood of green stink bugs. Her project began two years ago as a simple middle school science fair project and took two years to complete. It was inspired by a good science teacher, Rita Hagevik, who was enrolled in the Entomology for Educators course. Marife is a classic example of a student who became turned on to science through the discovery process. According to Ms. Hagevik, "...

neither of Marife's parents are scientists nor do they know much about science ... Thank you for the course and for all of your help ... This is truly what education is all about."

c. Source of Funds - Hatch, State

d. Scope of Impact - National

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	Non-Federal	SY	PY	TY	CY
$98,358	$503,473	$20,031	$87,454	3.3	3.9	1.0	2.3

II. RESEARCH STAKEHOLDER INPUT PROCESS

The North Carolina Agricultural Research Service (NCARS) is committed to seeking, receiving and utilizing input from all stakeholder groups, including under represented groups and the general public. A significant portion of the input from individuals throughout the state comes from interactions of research scientists with county-based extension personnel and directly with producers, industry and other agribusiness representatives. Approximately 100 of the 350 research faculty also have extension appointments. These faculty are the primary day-to-day communication link between agribusiness, county extension offices and NCARS. Because their research and extension activities are directed toward the development-implementation phase of new knowledge and technology, they are constantly relating industry needs and suggestions to other researchers whose emphasis is more in the discovery phase. In addition, these faculty interact with county extension personnel in such a way that input from individual consumers is also effectively communicated to NCARS administration and faculty.

Stakeholder input utilized in determining research program directions is also received through numerous associations. NCARS interacts with 90 official commodity and agricultural industry associations from within North Carolina. A College of Agriculture and Life Sciences administrator is appointed as the official liaison for each of these associations and attends at least one, and sometimes more, of their meetings or conferences each year. During these meetings opinions and facts related to the needs and concerns of that industry sector are obtained through both formal presentations and informal conversations with attendees. The NCARS representative is always introduced early in the meetings so that any individual there can contact them and discuss whatever issues they desire. In addition, the College has employed a Director of Commodity Relations, who reports directly to the Dean and coordinates the activities of the liaisons. This individual also has responsibility to work with any association that has a need or concern relative to the College's programs, particularly if it might involve any state or federal legislation.

Of the 90 state agricultural industry associations, 24 provide funding to various research projects annually, usually on a competitive basis. In these cases, the association board gives NCARS information on high priority research areas to be used in the request for proposals and the board decides which proposals to fund. This is the most targeted type of stakeholder input, having a direct effect on research activities within NCARS.

NCARS is in the process of establishing an NCARS Advisory Council that will consist of three Advisory Committees composed of external stakeholders. These Advisory Committees will focus on the broad areas of

life sciences (biotech, genomic, pharmaceutical, etc. companies), production agriculture (animal and field & horticultural crop producers), and agricultural allies (agricultural chemical & equipment companies, processors & packers, financial institutions, regulatory agencies, etc.). Each Advisory Committee will have 10 to 15 members.

The Advisory Council will assist NCARS by:

- Advising the Director regarding NC research needs and priorities.
- Assisting in evaluation of current and proposed research activities through program reviews.
- Advocating for NCARS's agenda through promoting the importance of agricultural and life science research.

Each Advisory Committee will meet at least once per year to discuss Committee agenda items and prepare recommendations to NCARS on particular issues, solicited and unsolicited. The Advisory Council (all three Committees) will meet together with NCARS administrators, Department Heads and selected faculty once per year for Committee reports & recommendations, overviews of research programs and issues, consultation on the upcoming state and federal budget items, future concerns, etc. The Production Agriculture Advisory Committee has been established and met once in Fall 2000. Nominations for membership in the Agricultural Allies Advisory Committee is currently being solicited.

Many of the departments within the College of Agriculture and Life Sciences have formal advisory groups with stakeholder members that meet on a regular basis to provide input and guidance into the department's research programs. There are 21 such advisory groups among the 18 research departments that meet at least once per year, and their membership includes a total of 238 stakeholders from a wide range of agricultural interests. In addition, there are currently eight formal centers within the college with industry advisory boards that meet at least twice per year, adding another 55 stakeholders providing NCARS administrators and scientists input and direction for research programs.

The college has two major foundations that support NCARS research each year, the Agriculture Foundation and the Dairy Foundation. These foundations fund research projects and graduate students on a competitive basis across a wide range of areas. NCARS administration meets with the Research and Extension Committees of these foundations, approximately 70 members from Agriculture Foundation and 20 from Dairy Foundation, each fall to hear discussion on priority areas for research activity in all aspects of agricultural production and agribusiness. Then in late winter, these committees meet again to select and approve research projects for funding, which provides another opportunity for input on research priorities.

Finally, because the research faculty are also major stakeholders of NCARS, there is a CALS Research Committee, which consists of one elected representative from each department. The committee meets monthly to discuss and make recommendations to the NCARS director relative to policy and resource allocations.

III. PROGRAM REVIEW PROCESS

There have been no significant changes in the program review processes since the NCARS 5-Year Plan of Work was submitted.

IV. EVALUATION OF THE SUCCESS OF MULTI AND JOINT ACTIVITIES

NCSU faculty were involved in 48 Multistate Research Projects, 12 Information Exchange Groups, and 24 Southern Extension and Research Activities. These activities were all multistate, multidisciplinary and involved integration of research and extension. They continue to be an excellent vehicle for collaborative, coordinated research and a broad-based, systematic approach to solving problems relative to the Southern Region and the nation in general. Examples of multistate, multidisciplinary, integrated activities other than those included above are discussed below.

The **South East Small Fruit Consortium** is a multistate integrated activity between NCSU, Clemson and University of Georgia. Successful activities of the Consortium over the past year include the following.

- Cosponsored two FQPA pesticide risk assessment reviews at NCSU covering all the small fruit crops, involving specialists from the Carolinas, Florida, and Virginia.
- Sponsored a strawberry plasticulture extension agent training short course in NC involving 10 agents from the Carolinas and Georgia, and 9 additional agents from Arkansas, Maryland, Virginia.
- Sponsored a second strawberry plasticulture extension agent training short course in SC, which included 30 agents from the Carolinas and Georgia, plus 4 agents from Alabama and Arkansas.
- Cosponsored a bramble crop workshop during the Southeast Fruit and Vegetable Expo. in NC.
- Sponsored a blueberry production extension agent training short course across two locations in NC and GA, involving 15 agents from the Carolinas and Georgia.
- Awarded grants in the amount of $47,000 to researchers and extension specialists in the Carolinas and Georgia to fund applied research projects in 2001.

The **EPA/Six-State Consortium**, under which animal waste management research is supported by a combination of resources from EPA, member state institutions and the Animal and Poultry Waste Management Center (APWMC), is made up of Iowa State University, Purdue University, Michigan State University, Oklahoma State University, University of Missouri and North Carolina State University. Proposals considered for funding under these sources were submitted under priorities found on the website of the Lead Institution (www.aes.missouri.edu/rfpwaste/priority.htm/). The APWMC provides partial funding on five projects currently are led by Principal Investigators in North Carolina, Virginia, Mississippi, and Georgia. The projects include work on: a. dust particle and odor control in swine facilities; b. dietary manipulation to reduce swine odor; c. animal and poultry waste for sod production; d. dairy waste nutrient loss control; e. soil phosphorus benchmark levels. This work is underway. The APWMC has allocated $50,000 toward these efforts.

Over the last several years the **NC / SC Tomato Breeding Program** has evaluated numerous experimental tomato hybrids in grower fields in coastal South Carolina through a cooperative agreement between NC State University and Clemson Univ. Cultivars resulting from this cooperative research with adaptability to production in both states include 'Plum Dandy', a Roma-type tomato for fresh-market production, 'Floralina', a fusarium wilt race 3 resistant hybrid, and 'Sun Leaper', a high temperature fruit set hybrid. A new plum tomato hybrid ,NC 98128, with combined early blight and fusarium wilt race 3 resistance and the crimson gene for enhanced fruit color is planned for release as a named cultivar. The high temperature fruit set hybrid, NC 96365, is being

evaluated in replicated trial and large scale grower plantings in coastal SC to determine its potential for release. Recently, resistance breeding for tomato spotted wilt virus was initiated because of its severity in recent years in SC and increasing severity in NC. The cooperative effort has worked well with the overall objectives of the NC breeding program and has given the opportunity for evaluation of experimental hybrids in early season for adaptability to coastal areas of both states.

V. INTEGRATED RESEARCH AND EXTENSION ACTIVITIES

Research and extension activities are integrated within the College of Agriculture and Life Sciences at the administrative, programmatic, departmental and faculty levels. The directors of the N.C. Agricultural Research Service (NCARS) and the N.C. Cooperative Extension Service (NCCES) work closely together and coordinate all aspects of administration; including position management, state budget requests, budget allocation, facility management, and space utilization. Currently there is an integrated effort to more closely align administrative structure of the directors' offices with programmatic areas across research and extension in the college.

Programmatically, research and extension activities are integrated formally in a number of key areas through the efforts of faculty serving in the role of research and extension coordinator or as a center director. Examples of programmatic areas where this has been particularly successful are water quality, animal waste management, integrated pest management, sustainable agriculture, air quality, small fruits and specialty crops. These coordinator and center director positions are funded by both NCARS and NCCES and operating funds are allocated from both offices.

In all college departments that have both research and extension faculty, these faculty are housed together and interact on a day-to-day basis in all operational and programmatic aspects of the department. This also promotes close interaction with faculty who teach, most of whom have research or extension appointments.

The most complete integration of research and extension occurs at the individual faculty level. Almost 100 of the 350 college faculty with research appointments also have extension appointments. In fact, most of these split-appointment faculty have 50 to 80 percent extension appointments, so their research programs are specifically designed to support their extension programs. These faculty serve as a strong link between those faculty who have a majority research appointment (usually split with teaching) and the county-based extension field faculty and state's agricultural industries. Working closely with the more basic, discovery-oriented research faculty, these research/extension faculty, in conjunction with county field faculty, bring new knowledge and technology to the producers and agribusiness through development, field testing and demonstration.

Since all faculty with research/extension split appointments have an approved federal or state research project cataloged on the CRIS database, the NCARS expenditures and personnel commitment for the research aspects of their activities can be documented. The following table shows the Hatch expenditures during 2000 for these projects under the NCARS research program areas and subprogram areas. The total expenditure of $1,201,999 million is 24% of NCARS's Hatch allocation.

NCARS Research/Extension Split Appointments (2000)
Total Expenditures

National Goal NCARS Program Area and Subprogram Area	Total Hatch
1. An Agricultural System that is Highly Competitive in the Global Economy	
1. Technologically Integrated and Sustainable Crop and Livestock Production Systems	
Crop Production Systems	$188,495
Animal Production Systems	$156,863
Biological Systems	$0
2. Plant and Animal Germplasm, Genetic Resources and Conservation, and Plant Improvement	
Crop Improvement	$150,496
Animal Improvement	$0
3. Plant Protection Strategies (Forest, Agronomic and Horticultural Crops)	$259,944
4. Animal Diseases and Animal Health	$6,516
5. Farm Business Management, Economics and Marketing	$146,061
6. Product Development	$61,847
2. A Safe and Secure Food and Fiber System	
7. Food and Fiber Processing, Safety and Quality	$36,023
3. A Healthy and Well-Nourished Population	
8. Human Nutrition and Human Health	$0
4. An Agricultural System Which Protects Natural Resources and the Environment	
9. Soil, Water and Air Quality Conservation and Management	$172,018
10. Forest, Pasture, Wildlife and Fish Resource Conservation and Management	$0
5. Enhanced Economic Opportunity and Quality of Life for Americans	
11.Individual, Family and Community Economic Development and Quality of Life	$23,736
Grand Total	$1,201,999