United States Department of Agriculture

Research, Education and Economics
Agricultural Research Service

Southern Insect Management Research Unit

Stoneville, MS

2012 Annual Progress Report
&
2013 Research Plans

Table of Contents

Mission Statement

Southern Insect Management Research Unit
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The mission of the Southern Insect Management Research Unit (SIMRU) is to generate new knowledge of arthropod pest biology, ecology and management and integrate this knowledge into contemporary farming systems that will promote economical and environmentally stable pest management practices for the southern U.S.

The vision of SIMRU is to be a recognized center of innovation for negating agricultural pest problem through deployed scientific knowledge of pest biology, ecology and management options.

Disclaimer and Purpose of Report

This report summarizes progress made on research objectives for 2012 and plans for research activities in 2013.

Many of the results are preliminary and others are being released through established channels. Therefore, this report is not intended for publication and should not be referred to in literature citations.

Intent of this report is to give the reader an overview of the Southern Insect Management Research Unit (SIMRU) activities. The activities (progress and plans) address the research unit mission. Formal annual reports of research progress as submitted to the CRIS system are included in the summary.

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Overall Summary and Perspective of 2012 SIMRU Activities

The Southern Insect Management Research Unit (SIMRU) remains a cohesive team of students, research technicians, scientists and administrative support focused on a vision of innovation to negate agricultural pest problems. While the Unit has a number of strengths and advantages, including Agency support and a long history of commitment to Delta agriculture, the Unit's greatest asset is a cooperative spirit and the linked capabilities of Unit employees. In 2012, this included a total of 27 STEP employees, 6 LA appointments and temporary term employees, 27 permanent research technicians, biological aids and administrative support employee, and 10 Cat 3, Cat 2 and Cat 1 scientists. This report includes reference to 58 scientific publications and 61 scientific presentations resulting from SIMRU cooperative efforts internally and with valued university collaborators. Active specific cooperative agreements in 2012 included long-term projects with the Mississippi State University Department of Biochemistry, Molecular Biology, Entomology and Plant Pathology, Mississippi State University's Delta Research and Extension Center, and Alcorn State University. A new project was initiated with Cornell University in 2012.

Unit-wide activities in 2012 included an orientation for STEP employees on May 30, STEP employee reports of learning activities on July 31, a Unit-wide "goodbye" cookout for STEP employees on August 2, a Thanksgiving luncheon on November 16, and a Christmas luncheon on December 17. SIMRU also organized a series of research discussion with key clientele groups during the spring. These included a meeting with the Mississippi Agricultural Consultants Association on March 19, a meeting with major commodity groups (Cotton Incorporated, National Corn Growers Association, National Cotton Council, United Soybean Board) on April 12, and review of SIMRU research with National Program Staff on May 2. Notes from these research discussions highlight major issues for future programming and copies are included in the appendix of this 2012 Annual Report.

Recruitment of new scientific talent remains a top priority for SIMRU. Five ARS employees from the Formosan Subterranean Termite Laboratory in New Orleans and entomology related units at Weslaco, Texas were relocated to SIMRU but none actually physically moved. The Unit completed 2012 with several vacancies including a Cat 1 scientist position, 2 Cat 2 scientist positions and several permanent and temporary research technician positions. A highlight of 2012 was the arrival of Dr. Katherine Parys. Katherine received her Ph.D at LSU and will be working on tarnished plant bug ecology. The Unit is actively planning for recruitment and identification of new personnel in 2012.

Tabatha Nelson and Lou Andrews received GS promotions in 2012. Lou Andrews, Ryan Jackson, Maribel Portilla, Gordon Snodgrass, Chad Roberts, Michelle Mullen, O.P. Perera, Chris Johnson, and Sandy West received within-grade step increases in 2012.

Work continues on renovations to Building 1. The Unit expects to move to new renovated space on the third floor during the spring of 2014. Renovations to Building 5 and the greenhouse were made in 2012 with a longer range plan for further improvements and additional rough laboratory space. SIMRUs lease on the Livingston farm property was discontinued in 2012, but a new site (Prewitt Farm) was obtained for research in 2013.

This annual report of information is a benchmark of activities for accountability and long-range strategic planning. It involves efforts from all SIMRU employees. I welcome feedback on the information and suggestions to further improve the report, and more importantly the overall effectiveness of our research.

I extend my appreciation to SIMRU employees and acknowledge their work documented in this 2012 report.

Randall G. Luttrell
Research Leader

CRIS Projects

Research Project: ***Insecticide Resistance Management and New Control Strategies for Pests of Corn, Cotton, Sorghum, Soybean, and Sweet Potato***

Project Scientists: Ryan Jackson (Lead Scientist), Clint Allen, R. G. Luttrell, O. P. Perera, G. L. Snodgrass, Y. C. Zhu
Project Number: 6402-22000-063-00D **Project Type:** Appropriated
Start Date: Sep 01, 2010 **End Date**: Aug 31, 2015

Objectives: The long-term objective of this project is to develop an improved understanding of how the changing cropping landscape impacts insecticide resistance development and management of various insect pest species in order to increase profitability and sustainability of mid-South row crops. Objective 1: Improve tarnished plant bug control and insecticide resistance management by gaining new information on the pest's ecology and biology using multi-disciplinary approaches, e.g. molecular genetic tools, stable carbon isotope analysis, gene expression and proteomics, and insecticide resistance assays coupled with field sampling. Objective 2: Determine the effect of bollworm ecology (corn earworm) on resistance to pyrethroid insecticides by developing and utilizing genetic markers linked to resistance traits, stable carbon isotope analysis, gossypol detection in adult insects, and insecticide resistance monitoring. Objective 3: Develop pest control strategies for the U.S. Mid-South's Early Soybean Production System by determining accurate treatment thresholds, understanding the impact of changing cropping systems on farm-scale pest ecology, and developing effective insecticide resistance management practices for the stink bug complex, three-cornered alfalfa hopper, bean leaf beetle and soybean looper. Objective 4: Improve low input systems of pest control for sweet potato by evaluating the efficacy and proper use of newly registered insecticides to enhance their integration with crop rotation and other low cost control strategies.

Approach: We plan to improve tarnished plant bug control and insecticide resistance management by gaining new information on the pest's ecology and biology using multi-disciplinary approaches. Analytical techniques, such as stable carbon isotope analysis, will be used to determine the influence of C4 host plants, such as field corn or pigweed, on populations of tarnished plant bug adults infesting cotton fields. This information will identify sources of tarnished plant bugs that may lead to alternative control measures prior to infestations into cotton fields. Tarnished plant bug populations will be monitored for resistance to various classes of insecticides commonly used by mid-South producers. This will provide real-time information to decision makers that will allow them to adjust their control recommendations based on the type of resistance that is found in their area of the mid-South. Detoxification enzyme activity surveys will be conducted in an effort to correlate and quantify insecticide resistance levels in field populations of the tarnished plant bug. Molecular genetics techniques will be conducted on tarnished plant bug populations that could lead to assays to evaluate the extent of field resistance in tarnished plant bug populations and provide input for insect management decisions. We also plan to determine the effect of bollworm ecology (corn earworm) on resistance to pyrethroid insecticides. Analytical techniques, such as stable carbon isotope analysis and a gossypol detection technique, will be used to determine the impact of bollworm larval plant host on pyrethroid resistance levels measured in adults collected from pheromone traps. Molecular genetics tools will be used to identify candidate genes and biological pathways associated with insecticide resistance in bollworm populations. Successful identification of loci associated with insecticide resistance and the development of genetic markers for those will provide a method to obtain quantitative estimates of field evolved resistance by estimating the allele frequencies via population studies. We will also develop pest control strategies for the U.S. Mid-South¿s Early Soybean Production System by determining accurate treatment thresholds and developing effective insecticide resistance management practices for the stink bug complex and bollworm. Field studies will be conducted to evaluate treatment thresholds for stink bugs and bollworms in early season soybeans. Stink bug populations will be monitored for potential resistance to various classes of insecticides, and this effort will provide real-time information to decision makers regarding the proper use of insecticides for control of these pests. We also plan to improve low input systems of pest control for sweet potato by evaluating the efficacy and proper use of newly registered insecticides to enhance their integration with crop rotation and other low cost control strategies. Field and laboratory studies will be conducted to determine the impact of crop rotation on populations of insect pests of sweet potatoes, as well as information of insecticide efficacy and proper application techniques.

Summary: For tarnished plant bug (TPB), contribution of pigweed and corn to adult populations within cotton fields can now be estimated using stable isotope analyses. Initial estimates indicate that ~80-90% of TPB adults collected from cotton fields in the Mississippi Delta during late June and early July completed nymphal development on a C4 host, primarily field corn. This may provide an opportunity to manage TPB populations prior to movement into cotton. Insecticide resistance monitoring in TPB populations indicated that control issues with acephate and pyrethroids will continue. TPB populations continue to be susceptible to thiamethoxam, imidacloprid, and novaluron. MS producers and consultants utilize this information when selecting insecticides for TPB control. TPB transcriptome sequence reads and their assemblies were made available to the public by depositing in the National Center for Biotechnology Information database. More than 200 xenobiotic processing gene transcripts were identified, and sequences were deposited in the database. Over 20,000 polymorphic genetic markers in expressed gene transcripts were also identified. Analysis of 6,688 genes of TPB using microarray revealed 6 esterase, 3 P450, and one glutathione S-transferase (GST) gene(s) that were significantly up-regulated. Economic and ecological impacts of wide-scale adoption of Bt cotton and insecticide use on grower profits and perceived risks of bollworm (BW) damage are being measured. These impacts have potential influence on BW resistance evolution to insecticides and Bt toxins. Pyrethroid susceptibility estimates in BW across the cotton belt did not vary from those generated during the previous three years; however, pyrethroid susceptibility estimates over the last 4 years have generally decreased compared to estimates generated during the late 1990’s. No patterns of pyrethroid or Bt susceptibility were identified in BW collected from different cropping landscapes. BW genomic sequences (n=392) containing xenobiotic processing genes and insecticide targets were identified by sequencing a BCA library. Over 23,000 microsatellite markers were identified from the genome of the BW. Sequencing and assembly of the BW transcriptome were completed, and microarrays were developed for gene expression analysis. In soybeans, stink bug species were surveyed across the MS Delta to document temporal and spatial dynamics of stink bug populations. Late-instar stink bug nymphs (green, southern green, and redbanded) were approximately twice as tolerant as adults when

tested against organophosphorus or pyrethroid insecticides. Early stage nymphs should be targeted for insecticidal control. Tracking wireworm populations in sweetpotato and corn is providing new information on the impact of these soil-inhabiting pests on sweetpotato damage and crop rotation influences. Preplant applications of chlothianidin, chlorpyrifos, and imidacloprid reduced sugarcane beetle damage to sweetpotato in a large field cage study. Chlorpyrifos applications had no effect on reniform nematode populations in a study with insecticides applied alone and in combination with potassium N-methyldithiocarbamate.

Research Project: ***Control of Tarnished Plant Bugs by Biocontrol and Other Methods***

Project Scientists: G. L. Snodgrass, R. G. Luttrell, M. Portilla
Project Number: 6402-22000-064-00D **Project Type:** Appropriated
Start Date: Jan 03, 2011 **End Date:** Jan 02, 2015

Objectives: Determine the effect of temperature and reproductive state on susceptibility of tarnished plant bugs to *Beauveria (B.) bassiana* (ARSEF 8889). Determine the effect of exposure to insect growth regulators (IGRs) and *B. Bassiana* (ARSEF 8889) on immature tarnished plant bug survival. Determine the effect of host plant and application timing (season) on susceptibility of tarnished plant bugs treated with ARSEF 8889 and IGRs (in situ).

Approach: The effect of temperature and reproductive state on the susceptibility of tarnished plant bugs to *Beauveria (B.) bassiana* (ARSEF 8889) will be determined in replicated laboratory tests. The two reproductive states tested will be normal reproductive adults and nymphs and diapausing adults and nymphs that produce diapausing adults. Temperatures tested will range from 10°C to 30°C. Insect growth regulators (IGRs) will be tested with nymphs in replicated laboratory tests to determine which IGRs are effective and the rate at which to use them. The most effective IGR(s) will be tested in laboratory tests in combination with ARSEF 8889 to determine the most effective combination treatment. Results from the laboratory tests will be tested in the field in replicated tests in cotton (for in-season plant bug control) and in the fall and winter on wild host plants (for control of the diapausing overwintering generation). The effect of IGRs and ARSEF 8889 treatment on beneficial arthropod populations will be evaluated in the field tests and with additional laboratory tests.

Summary: The effectiveness of ARSEF 8889 (NI8) against reproductive and diapausing tarnished plant bug (TPB) was evaluated in several laboratory tests at temperatures from 10° to 30° C. The fungus was found to be equally effective against reproductive and diapausing TPB with higher infection rates at the warmer temperatures. A replicated small plot test in cotton was conducted during July 2010. Treatments tested were NI8, NI8 + novaluron, novaluron, and an untreated check. Results were inconclusive because of adult movement between the plots. A large replicated test in cotton is currently being conducted in which plot size is one acre. This should allow us to have a valid evaluation of the results. A preliminary test was conducted in October and November 2010 in which NI8 was used alone and in combination with novaluron to kill overwintering TPB adults and nymphs on pigweed and tall goldenrod. Beneficial arthropods found on the wild hosts were also identified and their populations estimated before and after treatment. The novaluron and novaluron plus NI8 treatments were very effective in reducing numbers of nymphs on both wild hosts with infection rates as high as 41.5%. Infection rates among adults with NI8 were as high as 77.7%. This test will be conducted in October 2011 using replicated plots. The most abundant beneficial arthropods on both wild hosts were spiders in the families Thomisidae (crab spiders) and Salticidae (jumping spiders). Crab spiders made up 48.5% of the total number of beneficial arthropods while jumping spiders were 22.2%. Crab spiders and jumping spiders were evaluated in laboratory tests for susceptibility to NI8 infection. Crab spiders were mostly immune while a low percentage of jumping spiders were infected. Green lacewing, ladybird beetle and big-eyed adults were also tested in the laboratory for susceptibility to NI8. Infection rates were low for these predators.

ARSEF 8889 was evaluated for tarnished plant bug (TPB) control in cotton in 2011. The test was conducted under extreme conditions in that the temperature exceeded 90°F on every day of the test and the TPB population in the cotton was well established and above the treatment threshold in every plot when the test began. None of the treatments controlled the TPB population including a standard treatment with dicrotophos or acephate (tests with a glass-vial bioassay showed that the population was highly resistant to pyrethroid and organophosphate insecticides). The test will be repeated in 2012 and will be changed so that the first treatment application is made earlier when below threshold numbers are present. A second application will be made one week after the first application. Deposition of spores on different locations in the plants will also be determined and used to evaluate spray coverage and residual effectiveness for TPB control. A field test using ARSEF 8889 to control TPB in corn when it tassels and in soybeans during bloom will be conducted. Field tests in the fall to evaluate the use of ARSEF 8889 and novaluron for control of overwintering TPB on wild hosts will again be conducted In a cooperative effort between SIMRU and the Boyce Thompson Institute, the genome of Beauveria bassiana has been sequenced and will be published this year.

Research Project: ***Effect of Resistance on Insect Pest Management in Transgenic Cotton***

Project Scientists: O. P. Perera (Lead Scientist), Kerry Clint Allen, Ryan Jackson, R. G. Luttrell
Project Number: 6402-22000-065-00D **Project Type**: Appropriated
Start Date: April 26, 2011 **End Date:** March 31, 2016

Objectives: Determine the impact of a changing cropping landscape on host plant ecology and insect resistance management practices for bollworm using analytical techniques. Determine gene flow and migration patterns by analyzing tobacco budworm and bollworm populations in temporal and spatial scales using genetic and/or empirical/mathematical approaches. Identify possible mechanisms of resistance to Bt toxins by profiling gene expression patterns and develop a marker based genetic linkage map.

Approach: More than 95% of the second generation bollworm within each growing season utilizes field corn as a host. Impact of corn plants expressing multiple Bt toxins on the bollworm populations will be studied by comparing historical pheromone trap data with current and future population estimates influenced by increased acreages of Bt corn expressing multiple Bt toxins. Stable carbon isotope analysis will be used to identify bollworms using corn as a host plant. Influence of local cropping landscape on bollworm populations will be studied using sentential plots of conventional and Bt corn and cotton and early maturing soybeans. Large field cages will be used to evaluate the impact of pyramided-gene Bt corn hybrid/refuge system on resistance management strategies. Expressed genes of tobacco budworm and bollworm will be identified by transcriptome sequencing, and genetic markers developed from polymorphic nucleotide regions will be used in ecological genetic studies of tobacco budworm and bollworm populations. Gene expression profiles will be used to identify biological processes involved in physiological response to ingestion of Bt toxins. Markers developed for candidate loci associated with resistance to Bt toxins will be used to estimate allele frequencies in natural populations. Genetic loci under selection will be identified using statistical methods. A genetic linkage map of the bollworm developed using polymorphic markers will be used to study inheritance of loci of interest to Bt resistance.

Summary: This is the first report for the project 6402-22000-065-00D that started in April 2011. Field and laboratory studies have been initiated, and insect samples are being collected and held for future analyses. Twelve-month milestones will be complete upon the end of the cropping season.

Transcriptome of tobacco budworm was assembled using over 20 million nucleotide sequence reads. All nucleotide reads and assemblies were submitted to public databases. Glass slide microarrays containing 44,000 features were developed using curated transcriptome sequences. BW transcriptome sequencing using Roche 454 and Illumina platforms was completed. Assembly and bioinformatic analyses were performed to identify expressed genes in the transcriptome assembly. Nucleotide sequence reads were re-assembled (overlaid) using curated reference gene sequences to identify single nucleotide polymorphisms. Nucleotide reads and assemblies of tobacco budworm and bollworm were submitted to public databases.

Primary cell cultures generated from susceptible YDK strain and resistant KCB and CXC strains of tobacco budworm were treated with Cry1Ac and Cry2Ab toxins. Treated and control cells were harvested and total RNA and proteins were extracted. RNA extractions are being used in RNA-Seq based gene expression profiling experiments. Protein fractions were subjected to two-dimensional differential gel electrophoresis to identify differentially expressed proteins. The protein spots identified were excised from the genes and were submitted to a core facility for mass spectrometry based determination of amino acid sequences. Laboratory screening of bollworm larvae collected from transgenic corn plants was initiated to select a bollworm line resistant to Cry1Ac. Bollworm larvae collected from various field sites were used to establish laboratory strains to obtain genetic material for mapping studies.

Results from the initial year of this project indicated that field corn was still the primary host of *H. zea* during the growing season even though greater than 50% of the corn planted in the southern U.S. produces one or multiple Bt proteins. Bt corn hybrids that produce multiple Bt proteins suppress *H. zea* larval numbers and kernel damage, but yields do not necessarily reflect this. Laboratory colonies of *H. zea* were established from light trap samples taken in concentrated areas of corn, cotton and soybean production in the Mississippi Delta and assayed for susceptibility to Cry1Ac. Variable responses were obtained but no clear association with the different crop areas was evident.

Corn fields were surveyed after harvest to assess the density and maturity of volunteer corn in the fall as well as the abundance of corn earworm in non-Bt corn at various growth stages. Greenhouse and field trials examining the efficacy of various crosses of Bt and non-Bt corn varieties on bollworm were conducted during last year and are being repeated during 2012.

Helicoverpa zea colonies with increased tolerance to Cry2Ab and Cry 1Ac were established from insects collected from field locations in the Mississippi Delta. Back-cross genetic mapping populations were developed by mating these colonies with insects from a susceptible laboratory colony maintained at SIMRU and DNA extractions were completed from 96 insects for use in a marker based mapping study.

Nucleotide sequences from 14 DNA pools containing 36,500 clones of a bacterial artificial chromosome (BAC) library were obtained using high-throughput sequencing technology. The sequence reads were assembled to identify candidate Bt resistance genes and genetic markers associated with them. Nucleotide sequences from bollworm BAC clones and transcriptome are also being used to complete assembly and annotation of the bollworm genome by CSIRO, Australia.

Laboratory colonies of Bt resistant and susceptible Old World bollworm, *Helicoverpa armigera*, exposed to Cry1Ac were used to study the time course of midgut gene expression. RNA extracted from midguts of treated insects was used to obtain short nucleotide reads for RNA-Seq profiling. Validation of differential expression patterns observed in RNA-Seq experiments is in progress.

Computer model simulations examining the risk of corn earworm resistance development on corn expressing two Bt genes versus those expressing a single gene were carried out. At least

350 replicate simulations with randomly drawn parameters were completed for each of four risk assessments. When dual-gene Bt-cotton, planted with a natural refuge and single-gene corn planted with a 50% refuge was simulated, resistance to both toxins simultaneously never occurred within 30 years, but in 38.5% of simulations, resistance evolved to toxin present in single-gene Bt-corn (Cry1A). When both corn and cotton were simulated as dual-gene products, cotton with a natural refuge and corn with a 20% refuge, 3% of simulations evolved resistance to both toxins simultaneously within 30 years, while 10.4% of simulations evolved resistance to the Cry1A toxin.

2012 Research Program Accomplishments

Adams Research Program

In SIMRU and LSU AgCenter collaborated to evaluate six insecticide regimes for efficacy against tobacco wireworm in sweetpotato. These studies were conducted in large cages at the SIMRU location in Stoneville, MS. Beauregard sweetpotatoes were transplanted to four row plots in the 1/8 acre field cages (14 plots per cage). Preplant and layby treatments were applied with an ATV two row boom sprayer calibrated to deliver 12 GPA. Weekly treatments were applied with a backpack two row boom sprayer calibrated to deliver 2.5 gallons to 1/8 acre. Treatments were arranged in a RCB design and replicated four times. Sweetpotatoes were harvested from the two center rows of each plot. Yield, quality and insect damage were recorded and analyzed. **(Larry Adams, R. G. Luttrell and Tara Smith)**

During 2012 SIMRU submitted yield and quality results from five check lines and six numbered research varieties, in cooperation with researchers from Louisiana State University, North Carolina State University and Mississippi State University, to the National Sweetpotato Collaborators Group Variety Trials for the NSCG Annual Report. **(L. C. Adams, R. G. Luttrell and Chris Johnson)**

USDA, ARS, SIMRU completed the second year of a three year crop rotation project in 2012 studying the effects of wireworm populations when rotating sweetpotato with conventional corn, treated and non-treated seed, and Bt corn, treated and non-treated seed. Developing an accurate method to sample for wireworms in sweetpotato production is included in this project protocol. Wireworms were found sampling corn bait traps biweekly with a 24” shake box with a wire mesh bottom. Several growth stages of the wireworm larvae were collected throughout the growing season although collections continued to be very sporadic, as in 2011. Results of this study are being evaluated to consider if a third year would be productive. **(L. C. Adams and R. G. Luttrell)**

During the 2012 growing season SIMRU transplanted sweetpotato demonstration plots to illustrate the value in taking soil samples for nematode populations and applying a nematicide and preplant incorporated insecticide to control soil insects attacking the developing sweetpotato roots. Three Mississippi Delta locations, Sanders Farm, Mound Bayou, MS, Alcorn State University Research Farm, Mound Bayou, MS and Livingston Farm, Elizabeth, MS were transplanted with Beauregard 14 slips in mid May. Treatments were applied approximately two weeks prior to transplanting and included Lorsban, K-Pam, Lorsban and K-Pam, a grower field and an untreated control. Soil samples were taken preplant, mid season and preharvest to determine nematode populations. All locations were harvested at ~115 days. Yield, quality and insect damage were recorded and analyzed. **(L. C. Adams, C. Johnson)**

A summary of insect pheromone trapping of the *H. zea* (20th year) and *H. virescens* (21st year) was compiled in 2012. We continue to work with other SIMRU scientist in the *Bacillus thuringiensis* resistance monitoring program. The results of the long term trapping of these pests illustrate the decline of population dynamics since the introduction of transgenic crops in the Mississippi Delta. **(L. C. Adams, C. Johnson)**

Allen Research Program

A survey of looper and stink bug species inhabiting soybeans in Mississippi and Arkansas was continued during the 2012 growing season. Soybean fields were sampled in Holmes, Sunflower, Tunica, Washington, and Warren Counties in MS and in Desha County in AR. Fields were sampled with a sweep net and looper larvae obtained from sampling were placed on artificial diet and reared to adult for species identification. *Rachiplusia ou* , the gray looper, was collected in low numbers from May 16th through the end of July. The first soybean looper, *Chrysodeixis includens* larva was collected on July 2nd in Holmes County, MS. Only two cabbage looper larvae were collected and that was the first week of July in Sunflower Co., MS. The majority of the stink bug species observed this year were green stink bug, *Chinavia hilaris* and brown, *Euschistus servus*. The southern green stink bug, *Nezara viridula*, was collected in later planted soybean during August and September in some locations. The redbanded stink bug, *Piezodorus guildinii* was collected in low numbers, especially in Warren county during the end of August. **(C. Allen, L. Andrews)**

The residual activity of different rates of several insecticides on soybean looper, *Chrysodeixis includens*, was examined. Leaves from treated soybean plants were removed at weekly intervals for five weeks after treatment. Leaves were placed in petri dishes with agar and 5 neonate soybean looper larvae were placed on each leaf. Mortality was recorded 72 hours after larvae were placed on leaves. Mortality of larvae placed on leaves treated with Intrepid (methoxyfenozide) applied at 6 or 8 oz/A , Steward (indoxacarb) at 11.3 oz/A, and Tracer (spinosad) at 2 oz./A remained high for up to two weeks. Mortality of larvae placed on leaves treated with Belt (flubendiamide) at 3 oz/A remained high for three weeks. Mortality of larvae placed on leaves treated with Prevathon (rynaxypyr) applied at 27 oz/A remained relatively high up to 5 weeks after treatment. **(C. Allen, L. Andrews, R. Jackson)**

Tarnished plant bug adults were collected adjacent to cotton at two locations in Leland, MS during July 2011 and examined for the presence of pollen. Pollen grains are unique and can be used to identify plant species with which an insect has had previous contact. Plant bugs were collected at night from a white sheet with a blacklight attached. Insects were collected directly into a 1.5 ml tube and stored in a freezer until processing was finished during 2012. A method called "acetolysis" was used which utilizes sulfuric acid to dissolve insect cuticle and causes little harm to the exterior surface of most pollen grains. Slides were made of the resultant pollen residue and examined under a microscope. The number of pollen grains was counted and the pollen types were identified utilizing the USDA-ARS Areawide Pest Management Research Unit Pollen Reference Collection. Thirty-eight tarnished plant bugs were examined and at least one pollen grain was recovered from all specimens. Overall, 1183 grains from 29 families, 33 genera, and 24 plant species was identified. The diversity of pollen grains identified are evidence of the multitude of host plants that may be utilized by tarnished plant bug adults within an area. **(C. Allen, G. Jones)**

Reproduction and survival of tarnished plant bugs in soybean was examined in small field plots in Stoneville. Four different planting dates of a maturity group IV and V soybean variety was sampled with a drop cloth. On each date, tarnished plant bug nymphs were collected from drop cloth samples with an aspirator and brought back to the lab to determine the instar of development. Tarnished plant bug populations during 2012 were low in soybean plots compared with 2011. The highest populations of tarnished plant bug nymphs were collected during the last week of May on the earliest planting date. Densities approached 3 tarnished plant bug nymphs per 5 row feet on the maturity group V variety during the estimated R2 stage of development. Low numbers were recorded for all planting dates during the R2 and R3 growth stages through the first week of August. Although numbers of tarnished plant bug nymphs aren't nearly as high on soybean as those encountered on wild hosts or other crop hosts, the vast acreage of soybean grown in the state may be an important source of tarnished plant bug adults during some periods of the growing season **(C. Allen, L. Andrews)**

Jackson Research Program

The influence of field corn and pigweed on populations of tarnished plant bug adults infesting cotton in the MS Delta was studied using stable isotope analyses. Cotton fields adjacent to field corn and those greater than 1 mile from field corn were identified in four MS Delta counties. Tarnished plant bug adults were collected on a weekly basis from these cotton fields throughout the growing season and subjected to stable carbon and nitrogen isotope analyses for natal host determination. The proportion of tarnished plant bug adults collected from cotton that developed as nymphs on plants that utilized the C_4 photosynthetic pathway, primarily maize and pigweed, peaked anywhere from 79-92% during 2008-2009. Distance of cotton fields from maize did not influence the peak proportion of tarnished plant bug adults collected with a C_4 signature from cotton fields, the peak timing, or the peak duration. The timing of these C_4 peaks occurred from 28 June to 8 July, and the duration was between 13 and 19 days. Stable nitrogen isotope analyses of tarnished plant bug adults indicated that maize was the major contributor of C_4 individuals infesting cotton compared to pigweed. Nevertheless, pigweed produced a significant proportion of tarnished plant bug adults infesting cotton, and improved control of these weed species could potentially reduce tarnished plant bug infestations in cotton. Because maize makes up a significant portion of the cropping acreage in the MS Delta, this information can be used to estimate the timing of mass movements of tarnished plant bugs into cotton fields, thus allowing for more efficient use of insecticides for tarnished plant bug control within cotton. It may also allow for future targeting of tarnished plant bug populations in field corn prior to movement to cotton. **(R. Jackson, C. Allen, G. Snodgrass, and L. Price).**

Pyrethroid insecticides are used to control bollworms many crops; thus, selection for pyrethroid resistance within the landscape is potentially great even though there may not be much selection pressure in any single environment. A regional project was established to measure pyrethroid susceptibility in bollworm from May to September during 2008-2012 in nine states stretching from Virginia to Texas. Male moths collected from pheromone traps were tested for susceptibility to cypermethrin, a pyrethroid insecticide used historically in adult vial tests. Average survival at a discriminating dose of 5 µg/vial of cypermethrin during 2012 was similar to survival levels from the previous several years. Average survival exceeded 20% only in Louisiana and Virginia. Consistent with previous years, survival was highest in most states during July. A comparison of survival during July of 2008-2012 with survival using the same methodology from July 1998-2000 showed that survival has increased from an average of 8% to 19%. The greatest increases in resistance were found in Louisiana and Virginia. Preliminary carbon isotope analysis indicated that most of mid-summer moths developed as larvae on grasses, most likely corn. Currently, no evidence exists that supports claims of more pyrethroid resistant moths being generated in cotton (or other broadleaves) than susceptible moths. Future work will evaluate the utility of a larval vial test that will reduce the length of time necessary to determine the susceptibility of a bollworm population within a given field. (**R. Jackson, F. Musser, M. Mullen, and L. Price).**

Second generation Bt cottons that produce two Bt proteins often sustain economic damage from bollworms. Thus, supplemental insecticide applications for bollworm control in Bt cotton are commonly made. Ten field studies were conducted across the Mississippi Delta to evaluate the need for supplemental bollworm control in Bollgard II and WideStrike cottons, as well as to determine whether non-Bt cotton varieties would be competitive from a yield standpoint. Each variety was scouted independently, and insecticide applications of lambda-cyhalothrin (Karate Z) or chlorantraniliprole (Prevathon) were made when a larval threshold of 4 larvae per 100 plants was met. Bollworm larval threshold was met in the non-Bt cotton variety at all field sites in 2012, but thresholds were not met at all sites for Bt varieties.. Studies with significant heliothine pressure demonstrated a yield benefit from spraying both non-Bt and Bt cottons with either insecticide. Non-Bt cottons treated with insecticides produced similar yields to Bt cottons with or without supplemental insecticide applications. These preliminary data suggest that non-Bt cottons can be produced competitively compared to Bt cottons in the mid-South and also confirm the benefit of supplemental insecticide applications to Bt cotton under significant infestation from bollworm. **(R. Jackson, D. Adams, C. Allen, and R. Luttrell).**

Luttrell Research Program

The second year of a large-field cage study was conducted to compare within season crop injury, end-of-season yield and survival of fruiting forms on different conventional (ARK48, MD25, DP121, DP174) and Bt (DP0912, PHY375, DP1048) cottons managed under no insecticide, Karate and Prevathon treated systems. Extreme densities of bollworm and tobacco budworm were created in the 1/8 acre cages by releasing 200 bollworm and 200 tobacco budworm moths at 1st bloom and 1st bloom + 4 weeks. Results were similar to 2011 studies and field studies. Unsprayed conventional cotton did not produce economic yield, no yield in some instances. No differences were observed among varieties when managed under a Prevathon treated system. Yields of most varieties treated with Karate were statistically similar to those treated with Prevathon, except for PHY375. **(R. G. Luttrell, Chad Roberts, Clint Allen, Ryan Jackson)**

A preliminary field study was conducted in 2012 to measure impact of spraying tassel-stage corn and blooming early-maturity-group soybean with *Beauveria bassiana* (10^9 spores per acre) on tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) populations before they colonize cotton. Observations included bioassays of leaves for residual activity of *B. bassiana* against tarnished plant bugs, routine sampling of tarnished plant bug nymphs and adults in all three crops, routine within-season plant maps of cotton fruit retention and fruit damage, mechanical harvest of the center two rows in cotton plots, and end-of-season box mapping of plants from each cotton plot to determine yield and fruit survival by main-stem and branch node location.

Infection of tarnished plant bugs held on cotton leaves from the *B. bassiana* and novaluron plus *B. bassiana* was evident but less than 10%. This residual infectivity was low compared to infection measured on leaves from an adjacent large-plot study of cotton sprayed with *B. bassiana* at a rate of 10^{12} spores per acre (more than 25% infection). Analyses of tarnished plant bug densities and within-season fruit retention indicated infestation (peak densities of 5232/acre in some plots) and damage (61 to 86% retention of 1st position fruit) in cotton, but distinctive differences among treatments were not evident. Yield and end-of-season box maps were generally correlated with the small differences observed among treatments. Yield of cotton bordering soybean was slightly higher than that of cotton bordering corn, suggesting that soybean may have served as a trap crop. Trends in overall colonization of cotton by tarnished plant bugs across the area suggest that larger plots are needed to measure impacts on tarnished plant bug populations. (**R. G. Luttrell, Kenya Dixon, Chad Roberts, Owen Houston, Maribel Portilla, Gordon Snodgrass, Ryan Jackson)**

Studies in 2011 to develop a residual bioassay of *Beauveria bassiana* treated leaves and relate residual infectivity to spore counts on glass slides was continued in 2012. Leaves from treated field plots of cotton, corn and soybean were exposed to 1-day-old adults from SIMRUs laboratory colony in plastic cups for 24 h. After the 24 h exposure periods, insects were transferred to individual 1 oz cups containing a meridic diet developed by Portilla et al. for assaying tarnished plant bugs. Observations were made at routine intervals for 3-4 weeks following transfer to the diet. Maximum infection was typically noted by 10 days post-exposure to the treated leaves. Infection from field plots was low when the application rate was 10^9 spores per acre (~10%), but significantly higher (25%+) at higher dosages (10^{12} spores per acre). The process of counting spores was delayed for logistical constraints. Spores appear to remain on the slides for several months if kept in a dry environment out of direct sunlight. (**R. G. Luttrell, Kenya Dixon, Maribel Portilla)**

Helicoverpa zea moths were captured from light traps in areas predominated by cotton, soybean or corn production in the Mississippi Delta. Gravid females were taken to the laboratory to establish colonies for Cry1Ac susceptibility measurements in subsequent generations of the progeny. Data were recorded in trap capture numbers, survivorship and reproduction, and susceptibility to a range of Cry1Ac concentrations in a diet-overlay assay. Differences in susceptibility from colonies established at the different crop sites and at different times in the year appear to be small, but data analyses are incomplete. Overall densities of *H. zea* captured early in the season were extremely low in comparison to previous year studies. **(R. G. Luttrell, Chad Roberts, Kenya Dixon)**

Helicoverpa zea, *Heliothis virescens*, and *Spodoptera frugiperda* larvae from SIMRU colonies were fed cotton leaves from conventional (ARK48, DP121, MD 25, DP 174DP0912, PHY375) and Bt cottons (DP0912, PHY375, DP1048, PHY499) for 7 days. Observations of larval survival and development (instar) were made daily for a week at which time larvae were transferred to a meridic diet for subsequent observations at pupation. Observations were also made on subsequent generation survival, reproduction and susceptibility. As expected, mortality of larvae after 7 days on the different cottons varied with variety. Those fed on Bt cottons had high mortality with LT50's of 2-3 days. Those fed conventional cotton suffered mortality, but in most cases the majority of larvae successfully survived to the pupal stage. LT50s on conventional cotton were greater than 7 days. Subsequent observations on reproduction and 2nd generation susceptibility to Bt toxins were hindered by low sample size. **(R. G. Luttrell, Chad Roberts, Kenya Dixon)**

Perera Research Program

The time course of gene expression in Bt resistant and susceptible lines of *Helicoverpa armigera* challenged with Cry1Ac was porfile. **OP Perera, Karl Gordon, and Tom Walsh)**

Genomic DNA was extracted from H*elicoverpa zea* obtained by mating field collected Cry1Ac and Cry2Ab tolerant insects with laboratory strains. DNA samples will be sent to Cornell University to genotype the insects and to develop a genetic map. **(OP Perera)**

Bacterial artificial chromosome containing chitin synthase A and B (CS-A and CS-B) genes o*f H. zea* was identified and the nucleotide sequence was obtained. This 145,000 nucleotide genomic region revealed the genomic organization of the CS-A and B genes. A manuscript comparing the genomic organization o*f H. zea* CS genes with *H. armigera* is in final phase of writing. **(OP Perera, and P. D. Shirk)**

Expression of over 30 odorant binding proteins in *Lygus lineolaris* was profiled using microarrays and real time PCR. This collaborative project with Joe Hull, USDA-ARS, Maricopa and Gordon Snodgrass has already resulted in one publication and a second publication is in the final phase of editing. **(OP Perera, G. L. Snodgrass, J. Hull)**

Collaboration with Lukas Mueller of Boyce Thompson Institute, Ithaca, NY was initiated in 2012 to sequence, assemble, and annotate the genome of of *L. lineolaris.* Genomic DNA and BAC clones were used to prepare Illumina sequencing libraries and 2 flowcells of sequence data used to obtain a partial genome of *L. lineolaris.* **(OP Perera, and L. Mueller)**

Portilla Research Program

The potential of *Beauveria bassiana* strain NI8 and the growth regulator novaluron (Diamond ®) for tarnished plant bug control was evaluated. A diet was used that is suitable for bioassays of TPB from second instar to adult that required continuous observation over a period of several weeks. Fourth instar (97.5 ± SE 0.02), fifth instar (95.0 ± SE 0.03) and adults (95 ± SE 0.03) of TPB were more susceptible (infection %) than second (52.5 ± SE 0.07) and third instar (85.0± SE 0.05) to *B. bassiana*; while, second instar (100%), third instar (100%) and forth instar (97.5 ± SE 0.02) nymphs had higher growth inhibition (mortality %) than fifth instars (92.5 ± SE 0.04) after ten days of exposure to novaluron. No effects in longevity (days) were observed in adults (21.57 ± SE 0.9) treated with novaluron when compared with control insects exposed to water alone (20.47 ± SE 1.2), but both had highly significant greater longevity than adults exposed to *B. bassiana* (5.2 ± SE 0.2). Adults of TPB were maintained for over a month without changing the diet. The non-autoclaved diet is semi-liquid before it cools which facilitates the mechanics of diet packaging similar to food packaging or lepidopteran diet preparation. The solid artificial diet for *Lygus* bugs provides improved research capacity for studying the ecology and susceptibility of the insect to a number of different control agents including beneficial organisms, insect pathogens, and insecticidal toxins being developed for transgenic technologies. (**M. Portilla, G. Snodgrass, R. Luttrell, and Tabatha Nelson**)

Two isolates of *Beauveria bassiana* including the commercial strain GHA and the Mississippi Delta native NI8 strain were evaluated in the field for pathogenicity and infectivity against tarnished plant bug (TPB), *Lygus lineolaris* (Palisot de Beauvois). Thirty 2-d old TPB adults from a laboratory colony were placed in cages located on top and bottom parts of cotton plants in the field prior to spraying with *B. bassiana*. A total of 240 cage were used in the 40 plots (20 plots per concentration) (0.068 acre each) sprayed with four concentrations (spores / acre) and a control with each *B. bassiana* strain (4 plots / concentration, 6 cages / plot, 2 cages/ cotton plant). Concentrations sprayed (spores / acre) were $4.0x10^{10}$, $4.0x10^{11}$, $4.0x10^{12}$, $4.0x10^{13}$ of *B. bassiana* strain NI8 and $4.1x10^{10}$, $4.1x10^{11}$, $4.1x10^{12}$, $4.1x10^{13}$ of *B. bassiana* commercial strain GHA. All sprays included 1.5 ml of Tween-80 per gallon of spray. Sprayed insects were collected from the cages and placed individually on Lygus solid diet and observed for ten days under laboratory conditions. Mortality and sporulation from Lygus collected on top and bottom parts of the plants were recorded daily. Differences of mortality and sporulation on day 3, 5 and 10 were significant among concentrations for both isolates and locations. Based on the LC50 (lethal concentration) and LS50 (lethal sporulation) estimates determined by probit analysis of the concentration-mortality (top and bottom) and concentration-sporulation (top and bottom) relationships 10 days after spray, *B. bassiana* native strain NI8 with a LC_{50} of $6.5x10^{12}$ and LS_{50} of $1.7x10^{13}$ (spores / acre) was more infectious to TPB than the commercial strain GHA with a LC_{50} of $4.74x10^{14}$ and LS_{50} of $2.27x10^{15}$ (spores / acre). Overall, these results indicated that *B. bassiana* strain NI8 was superior to the commercially-available isolate suggesting that a 50% reduction of adult populations of *L. lineolaris* may occur 10 days after spray using a spray. Nine strains of *Beauveria bassiana* were re-isolated for four generations to determine specificity for *L. lineolaris*. Virulence of eight strains of *B. bassiana was* compared *vs*. our control NI8. No Improvement in specificity and virulence has shown NI8 neither the other strains. Each generation of *B. bassiana* powder was produced from a single spores isolated from laboratory infected *Lygus* adults. Variation of LC_{50} throughout generation for each *B. bassiana* strain was analyzed. (**M. Portilla, G. Snodgrass, R. Luttrell, and Tabatha Nelson**)

Laboratory studies are in progress to determined resistance of *L. lineolaris* to the entomopathogenic fungus *B. bassiana*. Progeny from infected survival adults have been treated for 9 generation and non resistance has been found. Although, a small percentage of adults of generations seven and nine took longer to die, differences in adult survival among generation were not observed based on the LIFETEST Log-rank statistic procedure of SAS. (**M. Portilla, G. Snodgrass,R. Luttrell and Tabatha Nelson**)

Field studies were conducted to determine the effect of solar radiation on the effectiveness of *B. bassiana* infection in *L. lineolaris*. The field results were compared with laboratory results. Four concentrations of two strains of *B. bassiana* (NI8 and GHA) were used. (**M. Portilla, G. Snodgrass, R. Luttrell, and Tabatha Nelson**)

Foliar distribution of *B. bassiana* spores on cotton plants at different developmental stages was evaluated. Four concentrations of *B. bassiana* were used and four applications from June to Sep were carried out. Foliar distributions were compared at four different heights of the cotton plants. (**M. Portilla, G. Snodgrass, R. Luttrell, and Tabatha Nelson**)

Preliminary studies to determine regulation of *L. lineolaris* population using *B. bassiana* were carried out. Over 30 thousand adults of laboratory *L. lineolaris* colony were used for this experiment. (**M. Portilla, G. Snodgrass, R. Luttrell, and Tabatha Nelson**)

Preliminary laboratory studies of *B. bassiana* susceptibility among different field populations of *L. lineolaris*. (**M. Portilla, G. Snodgrass, R. Luttrell, and Tabatha Nelson**)

The total number of trays prepared by Insect Rearing in 2012 was approximately 786. This was divided between the colonies of *zea*, *vir* and *faw*. The insects produced nearly 20,000 eggs from this production and over three million pupae. Several scientists requested special mixed dry diet and cupped diet. Upon request scientists were provided eggs and pupae to complete projects. Insect Rearing shipped eggs, larvae and pupae to teachers and scientists across the U. S. **(Essanya Winder, Henry Winters, Maribel Portilla and R. G. Luttrell)**

Snodgrass Research Program

Resistance to acephate (Orthene) was determined with a glass-vial bioassay in tarnished plant bug populations from 21 locations in the Delta of AR (4), LA (2) and MS (15) in June 2012. Resistance ratios of 3.0 or larger (which means the population would not be controlled in cotton with acephate) were found in 14 populations. Tolerance to acephate (resistance ratios of 2.25 to 2.90) was found in 6 of the populations. These results showed that resistance to acephate (which is incompletely dominant in inheritance) has remained stable since it was first found in 2005. The same 21 populations were also tested for pyrethroid resistance with a discriminating-dose bioassay. The average percentage mortality found for the 21 populations was 65.1%. Mortality above 70% indicates a susceptible population, so the populations found in the Delta in 2012 were on average resistant. **(Snodgrass and Jackson)**

Resistance to the neonicotinoid insecticide thiamethoxam (Centric) was monitored with a glass-vial bioassay at 21 locations in the Delta of AR (4), LA (2), and MS (15) in 2012. The resistance found was low and little change in resistance was found from 2011 through 2012. **(Snodgrass and Jackson)**

Beauveria bassiana (NI8 strain) and novaluron (Diamond) alone and in combination were evaluated along with a standard insecticide treatment (acephate or sulfoxaflur) for tarnished plant bug control in large (ca. 1 acre) replicated plots of cotton at Stoneville, MS in June-July 2012. The plots were sampled with a sweep net for tarnished plant bugs and beneficial arthropods, and drop cloth samples were used to estimate numbers of tarnished plant bug nymphs. Samples were taken on 20 and 27 June, and on 3, 9, 18, and 30 July. Treatments were applied with a high-clearance sprayer using 11.4gal/acre on 21 and 29 June, and on 12 and 24 July. Treatments were novaluron (9 oz/acre), *Beauveria bassiana* (NI8, > 8 trillion spores/acre applied in water with 0.05% Silwet L-77 surfactant), a combination treatment of novaluron with NI8 applied separately at the previously stated rates, a standard insecticide (acephate at 1lb/acre or sulfoxaflur at 2.5 oz/acre), and an untreated check. The treatments reduced overall numbers of adults compared to the check by 15, 16, 37.1, and 42% in the novaluron, NI8, NI8 + novaluron, and standard insecticide treatments, respectively. The treatment threshold for plant bugs is 15 adults and nymphs per 100 sweeps. This threshold was exceeded 7 times between 20 June and 9 July. All but one time (novaluron on 9 July) the threshold was exceeded in the check or NI8 treatments. Compared to the check, the NI8, novaluron, standard insecticide, and NI8 + novaluron treatments reduced mean numbers of nymphs found in the drop-cloth samples by 22.5, 35.4, 39.0, and 63.0%, respectively. In the NI8 + novaluron treatment, the mean number of nymphs exceeded the treatment threshold (3 nymphs/6 row ft) on two dates. This was the fewest number of times the threshold was exceeded among all treatments. The test results showed that the use of NI8 in combination with novaluron was as good as using a standard insecticide treatment in reducing numbers of plant bugs in cotton. However, the high rate of NI8 used is cost prohibitive for use in normal cotton production. In addition, there are several other insecticides that could be used with novaluron that are cheaper. One advantage in using NI8 with novaluron is that the treatment caused a much smaller reduction in numbers of beneficial arthropods in the test than the use of a standard insecticide. The NI8 + novaluron treatment also had the highest yield of cotton in the test. **(Snodgrass, Jackson, Luttrell, and Portilla)**

Zhu Research Program

Population variation and seasonal changes of susceptibility to different insecticides was investigated in field populations of the tarnished plant bug. Multiple field populations were collected from May to November in 2011 and from May to September in 2012, and were subjected to dose response assays and survival rate assays using standardized spray method. Six insecticides were tested, including acephate, imidacloprid, dicrotophos, thiamethoxam, permethrin, and sulfoxaflor (representing four insecticide classes: pyrethroids, organophosphates, neonicotinoids, and sulfoximine). Toxicity baseline (LC_{50}) was established with a laboratory susceptible strain. Survival rates to discriminating dose in field populations ranged from 10-99%. Data comparison to laboratory susceptible strain indicated that many field populations have developed 5-8-fold resistance ratios during growing season (May to September). Pooled population data showed a near linear increase in survival rates from 30% in May to 60% in September. Higher survival rates were detected in populations collected from Northeast Arkansas and Northwest Mississippi. **(Zhu, West, Luttrell)**

Insecticide resistance was monited in different crop systems. Fifteen locations were selected to represent cotton, cotton/corn/soybean rotating, and non-cotton crop systems in MS, AR, and LA (covering 200 miles in E-W and N-S directions). TBPs were collected each month from May to September. Besides the routine collections from these 15 fixed locations, TPBs were also collected from 15 other locations in AR and MS, and subjected to survival rate bioassay with dicrotophos and thiamethoxam. Results indicated that tarnished plant bug populations from cotton areas had 1.5-fold higher survival rate to dicrotophos and 1.7-fold higher survival rate to thiamethoxam than the bugs from non-cotton areas. The populations from mixture or crop rotating areas showed intermediate survival rate. **(Zhu, West, Luttrell)**

Selection of resistant tarnished plant bug was selected for resistance mechanisms to major insecticides (classes). High concentrations (~LC95) of commonly used insecticides, dicrotophos, thiamethoxam, permethrin, and sulfoxaflor, were used to select field-collected TPBs. Two ml of insecticide solution (4x higher than normal bioassay) was used to ensure through coverage. Survival rates could reach 26.4%, 16.3%, 58.5% after dicrotophos, thiamethoxam, and permethrin treatment, respectively. Higher survival rates were closely associated with spray intensity in cotton growing areas. No survivor was obtained from sulfoxaflor selections. **(Zhu, West)**

Major toxicity route of acephate and thiamethoxam were examined is tarnished plant bug. Insecticides at LC_{75} were sprayed individually and in different combination to bug, green bean, and rearing cup. Results indicated that spraying on bugs and/or on rearing cup produced significantly higher mortality in TPBs than spraying on green bean only. To examine residual toxicity of Centric deposited on cotton leaves, a serial of concentrations (37.5-9600 mg/L) of thiamethoxam were sprayed on excised cotton leaves. Results indicated that 5815 mg/L of thiamethoxam is required to generate 95% mortality. **(Zhu, Luttrell)**

Insecticide resistance mechanisms were studied using biochemical and molecular approaches. Enzyme Activity /Inhibition Assays were conducted to compare esterase, glutathione S-transferase, and P450 oxidase activities between susceptible and resistant strains of the tarnished plant bug. Microarray and real-time PCR were applied to examine global and major detoxification gene expressions between susceptible and resistant TPB. Results indicated that major detoxification enzyme activities were associated with resistance levels. Additional acephate selection could elevate both resistance levels and enzyme activities. Bioassay data and gene expression data indicated that many TPB populations have developed certain levels of multiple/cross resistance to commonly used insecticides. **(Zhu, Luttrell)**

2013 Research Plans

Adams Research Plans

Develop methods to determine spring populations of wireworms, rootworms, white grubs and sugarcane beetles in sweetpotato fields. **(L. C. Adams and R. G. Luttrell)**

Participate in the 2013 NSCG Sweetpotato variety trials. **(L. C. Adams and C. Johnson)**

Monitor and report populations of *H. zea* and *H. virescens* in the Mississippi Delta through pheromone trapping. **(L. C. Adams and C. Johnson)**

Continue collaborative research with Alcorn State University scientists studying sweetpotato insect identification, sampling and damage in the Mississippi Delta. **(L. C. Adams, R. G. Luttrell and Tahir Rashid)**

Evaluate treatments for sugarcane beetle control in cooperation with LSU research scientist in large field cages. **(L. C. Adams, R. G. Luttrell and Tara Smith)**

Second year of demonstration plots to illustrate the value in taking soil samples for nematode populations and applying a preplant nematocide and an incorporated insecticide to control soil insects attacking the developing sweetpotato roots in three Mississippi Delta locations, Sanders Farm, Mound Bayou, MS, Alcorn State University Research Farm, Mound Bayou, MS and SIMRU research farm, Leland, MS.
(L. C. Adams, R. G. Luttrell and C. Johnson)

Allen Research Plans

The spatial and temporal distribution of various stink bug species in the MS Delta will be examined. **(C. Allen, L. Andrews)**.

An evaluation of the reproduction and survival of tarnished plant bug in soybean will be continued. **(C. Allen, L. Andrews, G. Snodgrass)**

The species composition of bollworm and tobacco budworms in early and late planted soybeans in the MS Delta will be examined **(C. Allen, L. Andrews, D. Adams)**

An evaluation of sprayed and unsprayed plots for lepidoptern pests in early and late planted soybean and the subsequent impact on yield within production fields will be conducted **(C. Allen, D. Adams, L. Andrews, R. Luttrell)**

Jackson Research Plans

Research will continue to determine the natal hosts of tarnished plant bug adults that immigrate into cotton throughout the growing season, and efforts will expand to the hills region of MS. **(L. Price)**.

Bollworm populations will continue to be tested for susceptibility to various Bt toxins/technologies. We will attempt to identify a relationship between laboratory assay results and field performance of these populations on Bt technologies. **(M. Mullen)**.

Sentinel plots will again be placed throughout the MS Delta to evaluate the benefit of pyramided-gene, Bt cotton varieties for bollworm control. Economic returns based on differences between insecticide-treated and non-treated plots of the same variety will be the basis of comparison among Bt technologies. These Bt varieties will also be compared to non-Bt varieties at these sites. Additional plots will be located within the MS Delta to evaluate the need for overspraying soybeans for bollworm control, as well as the economic benefit of such applications. **(D. Adams, C. Allen, and R. Luttrell)**.

Luttrell Research Plans

Field studies on grower farmers will continue in 2013 to compare insect control, insecticide applications, yield and net profits on conventional and Bt cottons sprayed with pyrethroid or diamide insecticides and compared to unsprayed controls. **(Donny Adams, Clint Allen, R. G. Luttrell)**

Bollworm moths will again be captured from light traps in areas of predominant corn, cotton and soybean production. Reproductive rates will be determined and 1^{st} generation progeny will be exposed to Cry1Ac in diet overlay assays. **(R. G. Luttrell, Kenya Dixon)**

A third year of comparing *Beauveria bassiana* spray deposits on glass slides to assays of residual activity of the fungus against tarnished plant bug on cotton leaves will be conducted. Plans are to compare the assay of residual deposits to mortality of tarnished plant bugs caged in the sprayed plots prior to application. **(R. G. Luttrell, Kenya Dixon, Maribel Portilla, Gordon Snodgrass)**

A resistance monitoring program will be established to measure susceptibilities of heliothines and tarnished plant bugs to Bt toxins and major insect ides. (**R. G. Luttrell, Michelle Mullen, Kenya Dixon, Gordon Snodgrass, Clint Allen)**.

Perera Research Plans

Eight genomic DNA libraries have been prepared using genomic DNA of a single male from a highly inbred line of *L. lineolaris.* Libraries will be pooled to increase the sequence diversity and specific DNA size fractions will be used to obtain paired end reads. In addition, mate-pair reads from a large insert (~40 Kbp) DNA library are also planned to improve assembly of the genome. **(OP Perera)**

Continue studies on the genetic variation of detoxification genes to identify loci associated with insecticide resistance in Lygus and bollworm. Single nucleotide polymorphisms identified from the transcriptomes will be used in the population genomics studies. **(OP Perera)**

Complete studies on the transcriptomes of tobacco budworm, bollworm, and tarnished plant bug and prepare manuscripts. **(OP Perera)**

Continue genetic marker development for bollworm to develop linkage maps. **(OP Perera)**

Portilla Research Plans

Life table will be constructed *L. lineolaris* using different natural host. We will start with lab cotton plants. **(Maribel Portilla, Gordon Snodgrass, Tabatha Nelson, R.G. Luttrell)**

Larger field cotton areas and other host plants of *L. lineolaris* will be increased for study in 2013 to determine infection on present population of *L. lineolaris*. A spray rate of 4.0×10^{12} spores per acre of *B. bassiana* will be applied with mechanical sprayers. Cages with laboratory insects and field populations of insects will be used to evaluate infection at application. **(Maribel Portilla, Tabatha Nelson, Gordon Snodgrass, R.G. Luttrell)**

Snodgrass Research Plans

Different colonies of the tarnished plant bug will continue to be monitored in the laboratory. One colony is a highly inbred colony with the red-eye mutation. Two colonies with normal eyes are infected with different strains of bacteria, and the last colony is a susceptible strain from Crossett, AR. These colonies are used in cooperative research with O. P. Perera. **(Snodgrass and Perera)**

Work with Gerald Gipson will continue to produce enough conidia of the NI8 strain of *Beauveria bassiana* for use in different tests during the year. **(Snodgrass and Gipson)**

Test plant bugs from 20-25 locations in the Delta will be tested for resistance to thiamethoxam (Centric) using a glass-vial bioassay. Any resistant populations will be further evaluated in field and laboratory tests **(Snodgrass)**

Assistance will be provided to Dr. Parys on host plants and other basic biology of the tarnished plant bug in the Mississippi Delta. **(Snodgrass and Parys)**

Zhu Research Plans

Resistant colonies of TPB will be developed for a conventional and a novel insecticide and analyze cross resistance correlation and association with crop system will be analyzed. **(Zhu)**

Resistance mechanisms to imidacloprid, dicrotophos, thiamethoxam, permethrin in tarnished plant bug will be characterized using enzyme assay and gene expression analysis (real-time PCR and microarray. **(Zhu)**

Collaboration with LSU to study Bt resistance and Bt performance in sugarcane borer will continue. **(Zhu)**

Work with Jeff Gore to examine P450 activity in resistant cotton aphid will be continued. **(Zhu and Gore)**

Insecticide deposition/residues (through contract or collaboration) will be analyzed and correlated with residual toxicity to TPB. **(Zhu)**

2012 Specific Cooperative Agreement Research Accomplishments

Project Title: Low input systems of pest control for sweetpotato in the Mississippi Delta

Alcorn State University
Project Investigator: Tahir Rashid
Project State Date: 8/1/2011

Agreement No.: 58-6402-1-614
ARS Investigator: R. G. Luttrell
Project End Date: 8/31/2014

2012 Accomplishments:

Effect of Prohexadione-Ca on yield and insect damage to sweetpotatoes

Four sweetpotato varieties, Beauregard, Covington, O'Henry, and Puerto Rican were planted in split plot, randomized complete block design with 4 replications in ASU Extension/Research Demonstration Farm and Technology Transfer Center, Mound Bayou, MS. Prohexadione-Ca treatments (0 and 810 mg L^{-1} a.i.) were the main plots and cultivars were the subplots. Each plot consisted of 2 rows. Sweetpotato was transplanted to conventionally prepared raised beds at a rate of 10 plants per row, with 1.5 ft between plants within the row and 3.5 ft between rows. The control and treated plots were separated by 10 ft buffer. The experiment consisted of two regimens, irrigated and non-irrigated with 32 plots in each regimen. Drip irrigation was used in both fields as needed until the plants were established and then biweekly to irrigated field only. Preplant application of glyphosate (24 oz/acre) was made to burn down all weeds. Post-transplant weed control was accomplished by hoeing and gas powered push tiller. Prohexadione-Ca treatments were applied with a 5 gal backpack sprayer at 810 mg L^{-1} (140 g a.i. ha^{-1}) mixed with 1 mL L^{-1} of crop oil concentrate and 1mL L^{-1} urea ammonium nitrate. Plants were sprayed until run off. Control plots were sprayed with water mixed with 1 mL L^{-1} of crop oil concentrate and 1mL L^{-1} urea ammonium nitrate. Treatments were applied twice during the season, 2 weeks and 6 weeks after transplanting.

Effect on plant parasitic nematodes: Soil samples were taken from 4 random places in each plot to detect any difference in relative abundance of plant parasitic nematodes among treatments.

Data Collection: Vine length of sweetpotato plants were measured after 90 days of transplanting by randomly selecting 4 plants in each plot. Sweetpotato roots were harvested, washed and graded into jumbo, US#1 ans US#2. All roots were weighed and examined for any insect damage by counting the feeding scars on each root. Insect damaged roots were weighed for comparison.

Sampling of sweetpotato weevil in southern Mississippi by pheromone traps

Sweetpotato weevil pheromone traps were placed in Copiah County (Crystal Spring area) near ornamental sweetpotato research plots. Traps were also placed around sweetpotato research field in Claiborne County (Alcorn State main campus area). Eight traps were installed at each location. A trap was fitted on a 4-ft cane just above the plant canopy and loaded with 120 μg of sweetpotato weevil lure. The pheromone was replaced every 4 weeks. Traps were checked every 2 weeks.

Adult wireworm collection in new 4-wing bucket traps.

In our previous study wireworm adults especially *Conoderus vespertinus* have been significantly attracted to purple sticky traps. A new trap was designed with 4-wing purple sheets to collect live adult beetles through a funnel into the collection arena. Eight traps were installed around a sweetpotato research field in ASU Ext/Res Demo Farm and Tech Transfer Center, Mound Bayou, MS. Traps were checked twice a week for live *C. vespertinus* adults.

2013 Research Plans:

Evaluation of Prohexadione-Ca on sweetpotato yield and insect damage will continue during 2013. No sweetpotato weevil was detected in pheromone traps during 2012. Trapping will continue in sweetpotatoes in Claiborne County, Mississippi with same lure concentration. We were unable to establish a laboratory colony of *C. vespertinus* due to low catch of adult beetles in 4-wing bucket traps. The 4-wing traps will be reinstalled during 2013. Soil bait traps will be installed to collect wireworm larvae. Toxicity bioassays will be conducted against collected wireworms with biological extracted compounds.

Project Title: Bt risk assessment for Lepidopterous pests of cotton

Mississippi State University **Agreement No.:** 58-6402-8-274
Project State Date: 3/3/2008 **Project End Date:** 3/2/2013
Project Investigator: Fred Musser **ARS Investigator:** Clint Allen

2012 Accomplishments:

The bollworm (corn earworm) is a major pest target of Bt toxins in corn and cotton. In both crops, the insect is targeted with similar Bt toxins, so successive generations of this pest are potentially exposed to the same selection pressure. We are assessing this risk in several ways.

A major thrust of field research during the last 2 years has been to examine the role of volunteer corn on the evolution of resistance of the bollworm. A graduate student (Arun Babu) is undertaking several studies to examine this aspect of Bt resistance risk. We conducted a survey of corn fields after harvest to assess the density and maturity of volunteer corn in the fall as well as the abundance of corn earworm in non-Bt corn at various growth stages. We have also conducted greenhouse and field trials examining the efficacy of various crosses of Bt and non-Bt corn varieties on bollworm under stressed and non-stressed environments. A second graduate student (Ben Von Kanel) is evaluating the change in performance on cotton of bollworms that developed on Bt corn varieties compared to non-Bt corn varieties. He is also conducting bioassays of various crosses of these bollworm populations to try to determine the genetic basis of differences in performance.

A second method for assessing the risk of resistance development in corn earworm is through computer modeling. Kristine Edwards and Michael Caprio have continued to use and modify a computer model to address the risk of resistance that comes from changes in our agricultural landscape and the Bt technologies available to farmers. In addition to the modeling, they are working with a subcontractor to move the population genetics program from a Java/Linux platform to a Windows platform. The new application reduces the need for re-compiling and will make the program available to a broader PC community without the need for increased support or maintenance. The goal is to develop a program that is intuitive to the user and accurately models the parameters provided.

Host plant usage and pyrethroid insecticide resistance levels in bollworm continue to be monitored across the cotton belt. Cooperators in 9 states have trapped moths each year since 2007 and tested them for pyrethroid resistance. The moths are then frozen and sent to Ryan Jackson (USDA-ARS in Stoneville, MS) for carbon isotope analysis which indicates the type of host plant on which the larva fed. Data show high levels of pyrethroid resistance in Louisiana and more recently in Virginia. Resistance in other states has been generally low. Corn earworm larval hosts are almost all grasses during mid-summer, with more developing on broadleaves during spring and autumn periods. This trend is consistent in all states being monitored. There has been no indication that pyrethroid-resistant moths are more or less likely to develop on grasses than pyrethroid-susceptible moths.

One of the benefits of Bt crops is reduced insecticide usage. However, the emergence of tarnished plant bug (TPB) as a major cotton pest in the mid-south has reduced this benefit in cotton. We have initiated some work with TPB to improve our understanding of TPB ecology and physiology. Specifically we have examined the prevelance of microsporidia and viruses in wild populations. Further, we have compared development of TPB populations from different regions within MS on cotton and other crop hosts. We are also examining how TPB alter expression of several polygalacturonases depending on host plant, which could be very important for this highly polyphagous pest. This work will continue in 2013.

2013 Research Plans:

Finalize research, project will end March 2013.

Project Title: Bt risk assessment for lepidopterous pests of cotton

Mississippi State University **Agreement No.:** 58-6402-8-313
Project State Date: 7/1/2008 **Project End Date:** 7/1/2013
Project Investigator: Jeffery Gore **ARS Investigator:** Ryan Jackson

2012 Accomplishments:

Bollworm larvae were collected from Non-Bt and VT3P field corn in 2011 and 2012. Pupal duration and pupal weights were determined for the parental generation. Backcrosses and reciprocal crosses were made and the offspring neonates were subjected to dose mortality bioassays on lyophilized Bollgard II cotton tissue. Male bollworm larvae collected from VT3P field corn had a longer pupal duration compared to males collected from Non-Bt field corn. Female pupal duration was not significantly different for individuals collected from non-Bt field corn and VT3P field corn. Populations collected from VT3P field corn had higher pupal weights than larvae collected from Non-Bt field corn. In 2011, progeny from females reared on VT3P field corn had a higher LC50 compared to progeny resulting from females reared on Non-Bt field corn regardless of paternal host. In 2012, progeny from all reciprocal crosses and the backcross larvae of non-Bt had similar LC50 values. The progeny from the VT3P backcross had a higher LC50 value than all other crosses. Based on these results, bollworms collected from VT3P field corn are healthier and more robust than those collected on non-Bt field corn. These results suggest that there are multiple minor genes that influence bollworm survival on Bollgard II cotton. Those genes may be associated with resistance traits, but are most likely influencing overall fitness of larvae that develop on VT3P field corn. Results of these experiments will be important for developing resistance management plans in areas where dual-Bt toxin corn hybrids and dual-Bt toxin cottons are grown in close proximity. **(B. Von Kanel, J. Gore, D. Cook, R. Jackson, A. Catchot, and F. Musser: Agreement No. 58-6402-8-313)**

An experiment was conducted in 2012 to evaluate the impact of insecticide applications on dual toxin Bt cottons. Non-Bt, Widestrike, and Bollgard II cotton varieties were planted in a split-plot design with 4 replications. Each variety had a sprayed and unsprayed treatment. The sprayed plots were treated, as needed, with Prevathon, Belt, or Tracer to control lepidopteran insect pests. Overall, lepidopteran densities were relatively high in this trial. Overall, insecticide applications on significantly reduced the numbers of damaged squares and bolls on non-Bt cotton, but not on Widestrike or Bollgard II cotton. Insecticide applications targeting lepidopteran pests significantly increased yields of non-Bt and Widestrike cottons. In contrast, no significant differences were observed on Bollgard II cottons. These results demonstrate that dual-gene Bt cottons are not immune to injury from bollworm. As a result, management of bollworms in dual-gene Bt cottons with foliar insecticides may be an important component for resistance management **(J. Gore and D. Cook: Agreement No. 58-6402-8-313)**

An experiment was conducted in 2012 to determine the impact of sequential low rate applications of Prevathon on bollworm injury and yield in Bollgard II cotton. The rates of Prevathon used included 1.5, 3.0, and 6.0 fl oz/A. These treatments were co-applied with a tarnished plant bug application when tarnished plant bugs reached the current economic threshold of 3 per 5 row ft. Each rate was sprayed with either every tarnished plant bug application or every other application and compared to Prevathon and Belt sprayed at their normal use rates (27 fl oz/A for Prevathon and 3 fl oz/A for Belt). A total of six applications were made for tarnished plant bugs in this trial. Therefore, treatments 1-3 were sprayed six times and treatments 4-6 were sprayed three times. Treatments 7 and 8 were sprayed one time when bollworm densities reached threshold. All of the insecticide treatments reduced square and boll injury from bollworm in Bollgard II cotton compared to the unsprayed plots. Applications of 3.0 fl oz/A of Prevathon sprayed six times and 6.0 fl oz/A Prevathon sprayed three and six times provided similar levels of control to that observed with Prevathon sprayed at threshold with 27 fl oz/A. All insecticide treatments resulted in higher yields than untreated Bollgard II. These results suggest that low rates of Prevathon can be sprayed sequentially beginning prior to flowering and reduce the impact of bollworms in Bollgard II cotton. This approach can reduce input costs for growers and may serve as an effective resistance management tool in dual-gene cottons. Low rates of 3-6 fl. oz/A applied throughout the season may result in a third toxin being present in dual-gene cottons throughout the season and further reduce the selection pressure on the Bt genes. These preliminary results will need to be repeated and refined before specific recommendations can be made **(J. Gore, A. Adams, and D. Cook: Agreement No. 58-6402-8-313)**

A colony of bollworms was collected from Bollgard II cotton and given to SIMRU for further testing **(J. Gore and D. Cook: Agreement No. 58-6402-8-313)**

Insecticide resistance in all insect pests of cotton threatens the economic viability of dual gene Bt cottons. Increased costs of foliar insecticides associated with resistant insects compounded with technology fees of dual-gene cottons results in a significant economic cost for growers. Surveys of cotton aphid susceptibility to neonicotinoid insecticides were conducted from 2008 to 2012. Cotton aphids were collected from commercial cotton fields across Mississippi, Louisiana, Arkansas, and Tennessee. Additional populations were tested from Texas and North Carolina. Aphids were collected from fields where control failures with foliar neonicotinoids were reported. Additional collections were made from cotton fields in these states where no foliar applications of neonicotinoid insecticides had been made. Leaf dip bioassays were used to measure their susceptibility to neonicotinoids. Cotton aphids collected from fields where control failures had occurred showed significant levels of resistance each year. Mean LC50 values averaged across all collections increased from 12.75 ppm in 2010 to 60.06 in 2011 and 27.0 in 2012. All of the populations tested in 2012 showed moderate to high levels of resistance to thiamethoxam regardless collection site (sprayed or unsprayed field) **(J. Gore and D. Cook: Agreement No. 58-6402-8-313)**

2013 Research Plans:

Experiments evaluating the impact of bollworms on yields of Bollgard II and Widestrike cotton will be continued in 2013. **(J. Gore and D. Cook: Agreement No. 58-6402-8-313)**

Collections of bollworms from Bt crops will be continued in 2012. **(J. Gore and D. Cook: Agreement No. 58-6402-8-313)**

The graduate student project evaluating the impact of Bt corn hybrids on bollworm, *Helicoverpa zea* (Boddie), population dynamics, fitness, and subsequent damage in cotton will be continued in 2013. **(J. Gore, D. Cook, A. Catchot, and B. Von Kanel: Agreement No. 58-6402-8-313)**

Experiments investigating supplemental insecticide applications in dual-gene cotton genotypes will be continued and expanded in 2013. **(J. Gore and D. Cook: Agreement No. 58-6402-8-313)**

Experiments investigating corn earworm survival on silks from dual-gene corn hybrids will be continued in 2013. This experiment will be expanded to determine the role of cannibalism on the ability of individual larvae to complete development on dual-gene corn hybrids. **(J. Gore and D. Cook: Agreement No. 58-6402-8-313)**

Project Title: Economic analysis of Bt corn technologies and associated refuge systems

Mississippi State University	**Agreement No.:** 58-6402-0-459
Project State Date: 4/1/2010	**Project End Date:** 4/1/2013
Project Investigator: Steve Martin	**ARS Investigator:** Ryan Jackson

2012 Accomplishments: Field studies were conducted in 2010 and 2011 with corn hybrids possessing various Bt traits across the Mid-South to estimate the impact of single- and pyramided-gene Bt corn hybrids on bollworm populations, as well as to make an economic assessment of single- and pyramided-gene Bt corn/refuge systems. Single-gene Bt hybrids had little impact on bollworm populations infesting field plots, whereas pyramided-gene hybrids significantly reduced larval numbers, larval size, and the numbers of damaged kernels. Yields of corn hybrids varied over the two-year period and did not correlate well with larval survival and kernel damage estimates. Data are currently being compiled to conduct an economic analysis comparing the single-gene, 50% corn refuge system with the pyramided-gene, 20% corn refuge system.

2013 Research Plans: NONE

Project Title: Assembly and Annotation of *Lygus Lineolaris* (Tarnished Plant Bug) Genome

Cornell University
Project State Date: 6/1/2012
Project Investigator: Lukas Mueller

Agreement No.: 58-6402-2-719
Project End Date: 12/31/2014
ARS Investigator: OP Perera

2012 Accomplishments:

The size of the *Lygus lineolaris* genome, estimated using flow-cytometry, was determined to be approximately 900 million base pairs (MBp). Based on this data, it was estimated that over 150 billion nucleotides of sequence data is required for initial assembly of the genome. High-throughput sequencing of 16 pools containing approximately 2300 *Lygus lineolaris* recombinant bacterial artificial chromosome (BAC) clones each was carried out to obtain over 1.5 billion Illumina HiSeq2000 reads. A preliminary assembly of the genomic sequence data yielded over 400,000 contiguous genomic DNA sequence fragments (contigs), indicating that additional sequence data needs to be generated to increase the coverage and average length of the genomic DNA contigs.

In order to reduce the level of nucleotide polymorphisms that adversely affect genome assemblies, a single-pair mated line of insects was generated by mating of sibs of a highly inbred laboratory colony of *Lygus lineolaris* for 5 successive generations. Genomic DNA was extracted from individual insects to prepare small insert genomic DNA libraries containing 300-600 Bp inserts.

2013 Research Plans:

Small insert genomic DNA libraries will be size fractionated to select 250 and 400 Bp insert sizes for obtaining overlapping and non overlapping, respectively, paired-end sequence reads. In addition, randomly sheared genomic DNA will be used to construct large insert (approximately 40 KBp insert size) mate-pair sequencing libraries for improving the quality of the genome sequence with reference-guided assembly techniques. Assembled genomic DNA sequence data will be annotated using automated and manual annotation pipelines. In addition, assembled DNA sequence data will be used to as a reference to identify polymorphic genetic markers for use in genetic mapping and population genetic studies.

2012 Publications and Presentations

Publications

1. Adams, B., F. Musser, A. Catchot, D. Dodds, J. Gore, and D. Cook. 2012. Evaluation of cultural IPM practices for controlling tarnished plant bugs in cotton, pp. 959-963. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

2. Adams, B. P., A. Catchot, J. Gore, F. Musser, and D. Dodds. 2012. The impact of planting date and varietal maturity selection on tarnished plant bug damage and insecticide application frequency in cotton. J. Econ. Entomol. (Submitted: 8-12-2012)

3. Adams, A., J. Gore, D. Cook, and A. Catchot. 2012. Insect control in Mississippi with Transform, pp. 1061-1066. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

4. Adams, L. C., R. G. Luttrell S. R. Stetina ____. Product evaluation for reniform nematode suppression in Mississippi Delta Sweetpotato production, 2011. Plant Disease Management Reports American Phytopathological Society. (In review for submission)

5. Adams, L. C. and C. Johnson. 2011. National Sweetpotato Collaborators Variety Trials Summary of Data, USDA, ARS, SIMRU, Stoneville, MS. 2011 National Sweetpotato Collaborators Group Annual Report, National Sweetpotato Collaborators Group Meeting, Birmingham, Alabama, February 4-5, 2012.

6. Adams L. C., Luttrell R. G. and Smith T. 2011. Evaluation of various insecticide regimes for control of sugarcane beetle and wireworms in sweetpotato. ESA Arthropod Management Test 2012, Volume 37 Section E65.

7. Akin, D. S., J. E. Howard, G. M. Lorenz III, G. E. Studebaker, S. D. Stewart, D. Cook, J. Gore, A. L. Catchot, B. R. Leonard, S. Micinski, K. Tindall, A. Herbert, D. L. Kerns, R. E. Jackson, M. Toews, P. Roberts, J. Bacheler, D. Reisig, and J. Greene. 2012. Evaluation of automatic insecticide applications following preventative insecticides for thrips, pp. 1102-1106. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

8. Allen, K. C., and Jones, G. D. 2012. Utilization of pollen to examine insect foraging and movement. Mid-South Entomologists online journal

9. Allen, K. C., R. E. Jackson, G. L. Snodgrass, and F. R. Musser. 2012. Comparative susceptibilities of different life stages of the tarnished plant bug (hemiptera: Miridae) to three classes of insecticides. Southwestern Entomologist. 37(3):271-280

10. Allen, K.C., R. E. Jackson and R. G. Luttrell. 2012. Economic returns of Bt and Non-Bt cotton under different insect management strategies. Pp 1127. *In* Proceedings Beltwide Cotton Conference, National Cotton Council, Memphis, Tennessee.

11. Cook, D. R., J. Gore, S. D. Stewart, G. M. Lorenz, A. L. Catchot, B. R. Leonard, D. S. Akin, G. Studebaker, and F. R. Musser. 2012. Impact of spray adjuvants on insecticide performance, pp. 1115-1120. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

12. Dodds, D. M., A. L. Catchot, **J. Gore**, D. Cook, and K. Ford. 2012. Effect of seed treatment, insect infestation, and pesticide program on cotton growth and yield, pp 89. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

13. Domingues, Felipe A., L. Karina, A. Silva-Brandão, G. Abreu, O.P. Perera, C. A. Blanco, F. L. Cônsoli and C. Omoto. 2012. Genetic structure and gene flow among Brazilian populations of *Heliothis virescens* (F.) (Lepidoptera: Noctuidae). Journal of Economic Entomology. 105:2136-2146

14. Edwards, K. T., M. A. Caprio, K. C. Allen and F. Musser, ____. Risk assessment for insect resistance of dual-ene versus single-gene corn. Journal of Economic Entomology. (Submitted May 17, 2012)

15. Gore, J.**,** A. Catchot, J. Greene, B. R. Leonard, and G. Snodgrass. 2012. Evaluation of plant based thresholds for tarnished plant bugs in flowering cotton. J. Econ. Entomol. 105: 2007-2014.

16. Gore, J**.**, D. R. Cook, A. Catchot, F. R. Musser, S. D. Stewart, B. R. Leonard, G. Lorenz, G. Studebaker, D. S. Akin, and R. E. Jackson. 2012. Overview of spider mite research in the Mid-South, pp. 1107-1113. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

17. Guo, Z., Y. C. Zhu, F. Huang, R. Luttrell, and R. Leonard. 2012. Microarray analysis of global gene regulation in the Cry!Ab-resistance and –susceptible strains of *Diatraea saccharalis*. Pest Management Science 68:718-730 (Submitted January 24, 2012)

18. Hardke, J. T., R. E. Jackson, and B. R. Leonard. ______. Opportunities to manage fall armyworm (Lepidoptera: Noctuidae) on Bollgard II® cotton with reduced rates of insecticides. Journal of Cotton Science (Submitted)

19. Hardke, J. T., R. Jackson, B. R. Leonard, and J. H. Temple. ______. Fall armyworm (Lepidoptera: Noctuidae) development, survivorship and damage on cotton plants expressing insecticidal plant-incorporated protectants. Journal of Economic Entomology. (Submitted)

20. Hardke, J.T., J. H. Temple, R. Leonard, R.E. Jackson. 2011. Laboratory toxicity and field efficacy of selected insecticides against fall armyworm (Lepidoptera:Notctuidae). Florida Entomologist 94:272-278.

21. He, Y., J. Zhang, J. Chen, L. Li., L. Chen, P. Zxiao, and Y.C. Zhu. 2011. Influence of pymetrozine on feeding behaviors of three rice leafhopper using electrical penetration graphs. Journal of Economic Entomologlogy. 104(6):1877-1884

22. He, Y., Y.C. Zhu, and R. Luttrell, 2012. Adverse influence on reproduction and potential fitness cost in survivors of Orthene-treated tarnished plant bug, *Lygus lineolaris*. In: Program and Abstracts of the 56th Annual Conference of the Mississippi Entomological Association, October 24-25, 2011. Midsouth Entomologist 5(1): 18-28.

23. Huang, F., M. N. Ghimire, R. B. Leonard, Y., Zhu, and G. P. Head. 2012. Susceptibility of field populations of sugarcane borer from non-Bt and Bt maize plants to five individual Cry toxins. Insect Science. 19(5):570-578. DOI: 10.1111/j.1744-7917.2012.01507.x

24. Hull, J., E. J. Hoffmann, O. P. Perera, and G. L. Snodgrass. 2012. Identification of the western tarnished plant bug (*Lygus hesperus*) olfactory co-receptor (Orco): expression profile and confirmation of atypical membrane topology. Archives of Insect Biochemistry and Physiology. Doi:10.1002/arch.2142.

25. Jackson, R. E., K. C. Allen and Luttrell, R. G. 2012. Comparative benefit of Bt and non Bt cotton under different insect management strategies. Pp 1125. *In* Proceedings Beltwide Cotton Conference, National Cotton Council, Memphis, Tennessee.

26. Jackson, R. E., G. L. Snodgrass, K. C. Allen, O. P. Perera, and L. D. Price. 2012. Analysis of carbon and nitrogen isotopes for natal host determination of tarnished plant bug (Hemiptera: Miridae) adults. Southwestern Entomologist. 37:123-132

27. Jones, G. D., and K. C. Allen. ____. Pollen analyses of tarnished plant bugs. Palynology. (Accepted December 1, 2012)

28. Jurat-Fuentes, J. L., O. P. Perera, and M. J. Adang.________. Identification of a biomarker for resistance to genetically engineered insecticial crops. Information Systems for Biotechnology Virginia Tech University Trade Journal (Submitted)

29. Lorenz, G., S. D. Stewart, B. R. Leonard, A. Catchot, J. Gore, and D. Cook. 2012. Impact of foliar insecticide application on dual gene cotton, pg. 1114. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

30. Luttrell, R. G., and R. E. Jackson. 2012. *Helicoverpa zea* and Bt cotton in the United States. GM Crops and Food Biotechnology in Agriculture and the Food Chain 3(3):1-15 (Submitted 1/15/2012)

31. Luttrell, R. G., R. E. Jackson and K. C. Allen. 2012. Insecticide trated and untreated Bt and conventional cottons under high insect pressure in large field cages. Pp. 1126. *In* Proceedings Beltwide Cotton Conference, National Cotton Council, Memphis, Tennessee.

32. Luttrell, R. G., R. E. Jackson and K. C. Allen. 2012. Insect control without Bt. Pp. 10. In Proceedings Beltwide Cotton Conference, National Cotton Council, Memphis, Tennessee.

33. Musser, F. R., K. Knighten, and J. Gore. 2012. Sublethal impacts of Diamond (novaluron) on tarnished plant bug, pg 1101. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

34. Perera, O.P., C. A. Blanco, L. Ballard, K. L. Siva-Brandao, F. A. Domingues, and C. A. Abel. 2011. Evaluation of anonymous and expressed sequence tag derived polymorphic microsatellite markers in the tobacco budworm, *Heliothis virescens* (Lepidoptera: Noctuidae). Southwestern Entomologist 36(3):287-294

35. Perera, O. P., G. L., Snodgrass, K. C. Allen, R. E. Jackson, P. F. O'Leary, and R. G. Luttrell. 2011. The complete genome sequence of a single-stranded RNA virus from the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois). Journal of Invertebrate Pathology 109:11-19

36. Portilla, M., G. Snodgrass, and R. Luttrell. ____. A novel bioassay to evaluate the potenitial of *Beauveria bassiana* strain N18 and the insect growth regulator novaluron against *Lygus lineolaris* on non-autoclaved solid artificial diet. Journal of Insect Science. (Submitted October 1, 2012)

37. Portilla, M, G. L. Snodgrass, C. A. Blanco, D. R. Arias, J. L. Jurat-Fuentes, and D. L. Boykin. ____. Suceptibility and demographic parameters of populations of fall armyworm, *Spodoptera frugiperda* exposed to Cry1Ac and Cry1Fa proteins of *Bacillus thuringiensis*. Journal of Insect Science. (Submitted March 8, 2012)

38. Portilla, M., Snodgrass, G. and Luttrell, R. 2012. Non-autoclaved solid artificial diet for Lygus bugs and beneficial bugs. United States Patent. (Submitted March 2012)

39. Rashid, T. and L. Adams. 2012. Development of low input systems to control insect pests. Abstract in program for ASU Annual Field Day, Lorman, MS.

40. Rashid, T. and V. Njiti. 2012. Regulation of sweetpotato vine growth may affect pests and yield. Abstract ASU Annual Sweetpotato Jamboree, ASU Ext/Res and Demo Farm, Mound Bayou, MS.

41. Sanchez, J. A., M. La Spina, and O. P. Perera. 2012. Analysis of the population structure of Macrolophus pygmaeus (Rambur) (Heteroptera: Miridae) in the Palaearctic region using microsatellite marker. Ecology and Evalution. doi: 10.1002/ece3.420

42. Scott, W., F. Musser, A. Catchot, **J. Gore**, and D. Cook. 2012. Temporal and spatial distribution of two-spotted mite, *Tetranychus urticae*, in cotton, pp. 966-970. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

43. Siebert, M. W., J. D. Thomas, S. P. Nolting, B. R. Leonard, J. Gore, A. Catchot, G. M. Lorenz, S. D. Stewart, D. R. Cook, L. C. Walton, R. B. Lassiter, R. A. Haygood, and J. D. Siebert. 2012. Field evaluations of sulfoxaflor, a novel insecticide, against tarnished plant bug (Hemiptera: Miridae) in cotton. J. Cotton Sci. 16: 129-143.

44. Snodgrass, G. L., R. E. Jackson., O. P. Perera, K. C. Allen, and R. G. Luttrell .2012. Effect of food and temperature on emergence from diapauses in the tarnished plant bug (Hemiptera: Miridae). Environmental Entomology. 41:1302-1310 (Submitted 12/30/2011)

45. Snodgrass, G.L. 2012. A summary of 13 years of monitoring insecticide resistance in tarnished plant bug populations in the Mississippi River Delta. In Progrom and Abstract of the 58th Annual conference of the Mississippi Entomological Associating, October 24-25, 2011. Mid-South Entomologist 5(1):23-33.

46. Stewart, S., S. Steckel, G. Lorenz, A. Catchot, J. Greene, **J. Gore**, B. R. Leonard, M. McCarty, L. Crooks, S. Baker, M. Rinehardt, and W. Mullins. 2012. Comparative performance of TwinLink® and Bollgard II® on the control of caterpillar pests across multiple locations in the cotton belt, 2011, pp. 1121-1124. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

47. Ugine, T. A. 2011. The effect of temperature and exposure to *Beauverin bassiana* on tarnished plant bugs, *Lygus lineolaris* (Heteroptera: Miridae), population dynamics, and the broader implications of treating insects with entomopathogenic fungi. Biological Control. Biological Control 59(3):373-383

48. Ugine, T.A. 2012. Developmental time and age-specific life tables for *Lygus lineolaris* (Heteroptera: Miridae). Environmental Entomology. 41(1):1-10. http://dx.doi.org/10.1603/EN10210.

49. Von Kanel, B., A. Catchot, J. Gore, F. Musser, and R. Jackson. 2012. Susceptibility of cotton bollworm, *Helicoverpa zea*, collected from Genuity VT3 Pro corn on dual-gene transgenic cotton, pp. 976-980. *In* Proc. 2012 Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

50. Williams, L., Y. C. Zhu, G. L. Snodgrass, V. Manrique. 2012. Plant-mediated decisions by an herbivore affect oviposition pattern and subsequent egg parasitism. Arthropod-Plant Interactions. 6(2):159-169

51. Yang, Y., Y. Zhu, J. Ottea, C. Husseneder, R. Leonard, C. A. Abel, R. G. Luttrell, and F. Huang. 2012. Characterization and transcriptional analyses of cDNAs encoding three

trypsin- and chymotrypsin- like proteinases in Cry1Ab-susceptible and resistant strains of sugarcane borer, *Diatraea saccharalis*. Insect Science. 00:1-12. DOI: 10.111/j.1744-7917.2012.01514.x (Submitted 8/17/2011)

52. Zhao, X., Z. Ning, Y. He, J. Shen, J. Su, C. Gao, and Y. C. Zhu. 2011. Differential resistance and cross-resistance to three phenylpyrazole insecticides in the brown planthopper *Nilaparvata lugens* (Homoptera: Delphacidae). Journal of Economic Entomology 104(4):1364-1368

53. Zhu, Y. C. 2012. Acephate resistance and potential mechanisms in the tarnished plant bug. In: Program and Abstract of the 56th Annual Conference of the Mississippi Entomological Association, October 24-25, 2011. Midsouth Entomologist 5(1):18-28

54. Zhu, Y. C., and R. G. Luttrell. 2012. Variation of acephate susceptibility and correlation with esterase and glutathione S-transferase activities in field populations of the tarnished plant bug, *Lygus lineolaris*. Pesticide Biochemistry and Physiology 103:202-209 http://www.sciencedirect.com/science/article/pii/S0048357512000673) (Submitted 02/03/2012)

55. Zhu, Y. C., Z. Guo, Y. He, and R. G. Luttrell. 2012. Microarry andalysis of gene regulations and potential association with acephate-resistance and fitness cost in *Lygus lineolaris.* PLosOne. 7(5): e7586. DOI: 10.1371/journal.pone.0037586 http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0037586 (Submitted 1/24/2012)

56. Zhu, Y. C., Z. Guo, and C. A. Abel, 2012. Cloning eleven midgut trypsin cDNAs and evaluating the interaction of proteinase inhibitors with Cry1Ac against the tobacco budworm *Heliothis virescens* (F.) (Lepidoptera:Noctuidae). Journal of Invertebrate Pathology. 111: 111-120.

57. Zhu, Y. C., S. J. West, X. F. Liu, and Y. He. 2012. Interaction of proteinase inhibitors with Cry1Ac toxicity and the presence of 15 chymotrypsin cDNAs in the midgu of the tobacco budworm, *Heliothis virescents* (F.) (Lepidoptera: Noctuidae). Pest Management Science 68:692-701 (2012).

58. Zhu, Y. C., Y. He, and R. G. Luttrell. 2012. Acephate resistance and potential mechanisms in the tarnished plant bug. *In*: Program and Abstracts of the 56th Annual conference of the Mississippi Entomological Association, October 24-25, 2001. Midsouth Entomologist 5(1):18-28 (2012). http://midsouthentomologist.org.msstate.edu/pdfs/Vol5_1/Abstracts_MEA_2011.pdf

Presentations

1. Adams, L. C., and R. G. Luttrell. 2011. Insecticide application method and chemistry evaluation for sweetpotato production in the Mississippi Delta. Mississippi Entomological Association, Mississippi State, Mississippi (Poster)

2. Adams, L. C., R. G. Luttrell and C. Johnson. 2011. Insecticide application method and chemistry evaluation for sweetpotato production in the Mississippi Delta, 2010 product evaluation for reniform nematode suppression in Mississippi Delta sweetpotato production and 2010 evaluation of Monty's Plant Food Products to enhance yield for crops grown in the Mississippi Delta. Annual Mississippi Sweetpotato Production Meeting Calhoun County Extension Center, Pittsboro, MS.

3. Adams L. C., Luttrell R. G. and Smith T. Evaluation of various insecticide regimes in sweetpotato production for sugarcane beetle control in the Mid-South. National Sweetpotato Collaborators Group Meeting. Birmingham, Alabama, February 4-5, 2012.

4. Adams L. C. and Luttrell R. G. 2011 Product evaluation and varietal differences for reniform nematode suppression in Mississippi Delta sweetpotato production. National Sweetpotato Collaborators Group Meeting. Birmingham, Alabama, February 4-5, 2012.

5. Adams L. C. and Johnson C. 2011 USDA, ARS, SIMRU Sweetpotato Variety Trial Results. National Sweetpotato Collaborators Group Meeting. Birmingham, Alabama, February 4-5, 2012.

6. Adams L. C. and Johnson C. P. 2012 Sweetpotato Nematicide/Insecticide Demostration Study. 2012 Alcorn State University Sweetpotato Jamboree , Mound Bayou, MS, September 13, 2012.

7. Akin, D. S., E. Howard, G. Lorenz, G. Studebaker, S. Stewart, D. Cook, J. Gore, A. Catchot, B. Leonard, S. Micinski, K. Tindall, A. Herbert, D. Kerns, R. Jackson, M. Toews, P. Roberts, J. Greene, J. Bacheler, and D. Reisig. 2012. Evaluation of automatic insecticide applications following preventative insecticides for thrips. Beltwide Cotton Conf., Orlando, FL, January 2012.

8. Allen, C. 2012. Looper species inhabiting soybean in the Mississippi Delta. Entomological Society of America Southeastern Branch Meeting. March 6, 2012.

9. Allen, C. and G. Jones. 2011. Utilization of pollen to examine insect foraging and movement. Mississippi Entomological Association Annual Meeting, Little Rock, AR, Oct. 25, 2011

10. Allen, K. C. and R. E. Jackson. 2012. Landscape effects on Pest Management. Crop Management Seminar sponsored by Cotton Inc., Tunica, MS, November 8, 2012. (Invited)

11. Allen, K. C., R. E. Jackson, and R. G. Luttrell. 2012. Economic returns of Bt and non-Bt cotton under different insect management strategies. Beltwide Cotton Conferences, Jan. 6, 2012.

12. Babu, A., F. R. Musser, M. A. Caprio, D. Cook and C. Allen. 2012. Effect of pollen-mediated gene flow of transgene by a multi-toxin Bt corn variety on survivorship and growth of corn earworm. Entomological Society of America Southeastern Branch Meeting. March 5, 2012.

13. Brown, S., J. A. Davis, B. R. Leonard, M. O. Way, K. V. Tindall, C. Allen, and A. R. Richter. 2012. Evaluating the efficacy of methoxyfenozide on Louisiana, Texas and mid-southern soybean looper populations. Entomological Society of America Southeastern Branch Meeting. March 6, 2012.

14. Catchot, A., J. Gore, D. Cook, F. Musser, S. Akin, S. Stewart, G. Lorenz, R. Jackson, G. Studebaker, and B. R. Leonard. 2012. Coordinated research to address changes in spider mite infestations in cotton. Symposium on "Challenges and solutions for IPM in the mid-southern U.S." held at the 7th International IPM Symposium, Memphis, TN, March 2012.

15. Catchot, A., J. Gore, D. R. Cook, R. E. Jackson, and F. Musser. 2012. Management of insect pests in the Mississippi Delta. Beltwide Cotton Conf., Orlando, FL, January 2012.

16. Gore, J. Introduction to Integrated Pest Management. NRCS Training Tour. Stoneville, MS March 2012.

17. Gore, J. Control of Tarnished Plant Bug and Sub-lethal Effects of Diamond Insecticide. Mid-South Agricultural Consultants Meeting Sponsored by MANA. Memphis, TN, February 2012.

18. Gore, J. Insect Management in Mississippi Rice. Delta Research and Extension Center Rice Field Day. Stoneville, MS. July 31, 2012.

19. Gore, J. Cotton Insect Management. 2012 R. R. Foil Research Center Field Day. Starkville, MS. July 19, 1012.

20. Gore, J. Spider Mite Research in the Mid-South. Entomological Society of America – Southeastern Branch Annual Meeting, Little Rock, AR, March 2012.

21. Gore, J. Overview of Spider Mite Research in the Mid-South. 2012 Beltwide Cotton Conferences. Orlando, FL, January 2012.

22. Gore, J. Insect Control in Rice, Cotton, and Peanuts. 2012 Delta Crop Summit. Stoneville, MS November 2012.

23. Gore, J. Insect Control in Rice, Cotton, Peanuts, and Grain Sorghum. 2012 Row Crop Short Course. Starkville, MS December 2012.

24. Gore, J. Impacts of Bt Cotton: Past, Present, and Future. GMO's for IPM: Implications for Field Crops Symposium. 2012 Entomological Society of America Annual Meeting. Knoxville, TN. December 1012

25. Gore, J., A. Catchot, D. R. Cook, F. R. Musser, R. Jackson, S. D. Stewart, G. Lorenz, D. S. Akin, G. Studebaker, and B. R. Leonard. 2012. Spider mite research in the mid-South. Southeastern Branch Meeting of the Entomol. Soc. of Am. Little Rock, AR, March 2012.

26. Gore, J., D. R. Cook, A. Catchot, F. R. Musser, S. D. Stewart, B. R. Leonard, G. Lorenz, G. Studebaker, D. S. Akin, and R. Jackson. 2012. Overview of spider mite research in the mid-South. Beltwide Cotton Conf., Orlando, FL, January 2012.

27. He, Y., Y. C. Zhu, and R. G. Luttrell. 2011. Adverse influence on reproduction and potential fitness cost in survivors of Orthene-treated tarnished plant bug, *Lygus lineolaris*. Mississippi Entomological Association, Mississippi State, MS. (Poster)

28. Huang, F., Ghimire, M., Leonard, B.R., Y. C. Zhu., Bai, Y., Zhang, L., Yang, Y. 2011. Susceptibility of eight Cry1Ab corn-resistant strains of sugarcane borer to three individual Cry toxins. The 59th Annual Meeting of the ESA Nov 13-16, 2011. Reno-Sparks Convention Center, Reno, NV.

29. Jackson, R, A. Catchot, J. Gore, and S. Stewart. 2011. Increased survival of bollworms on Bollgard II cotton compared to lab-based colony. Symposium entitled What's going on with dual-gene Bt cotton? Why are we spraying more for caterpillar control?. 2011 Beltwide Cotton Conference, Atlanta, GA.

30. Jackson, R. 2011. Bt cotton resistance monitoring update. 38th Annual Conference of the Mississippi Agricultural Consultants Associations, Mississippi State, MS. (Invited)

31. Jackson, R. 2011. Management of bollworms in dual-gene Bt cotton: is it worth it?. Row Crops Short Course sponsored by the Mississippi State University Extension Service, Mississippi State, MS, December 2011 (Invited)

32. Jackson, R. 2011. Management of cotton bollworms in dual-gene Bt cotton: is it worth it? Row Crop Short Course, Starkville, MS. (Invited)

33. Jackson, R. 2011. Pyramided-gene Bt cotton: can lab bioassays confirm or deny field resistance? West Texas Agricultural Chemicals Institute, Lubbock, TX. (Invited)

34. Jackson, R. E., K. C. Allen, and R. G. Luttrell. 2012. Comparative benefit of Bt and non-Bt cotton under different insect management strategies. Beltwide Cotton Conference, Orlando, FL.

35. Jackson, R., C. Allen, and R. Luttrell. 2011. Comparative benefit of Bt technologies in the Mississippi Delta. 58th Annual Conference of the Mississippi Entomological Association, Mississippi State, MS.

36. Jackson, R., C. Allen, and R. Luttrell. 2011. Value of transgenes in early and full season cottons for bollworm/tobacco budworm control under different insecticide spray systems. U.S. Cotton Breeder's Tour, Stoneville, MS. (Invited)

37. Jackson, R., G. Snodgrass, J. Gore, F. Musser, and R. Leonard. 2012. Insecticide resistance in the mid-South: an evolving problem. Symposium on "Challenges and solutions for IPM in the mid-southern U.S. held at the 7th International IPM Symposium, Memphis, TN, March 2012 (Invited).

38. Jackson, R., S. Stewart, C. Allen, G. Lorenz, J. Greene, and J. Gore. 2012. Performance of Bt cotton technologies and supplemental insecticide applications against bollworms. University of Tennessee Cotton Focus Meeting held in conjunction with the Mid-South Farm and Gin Show, Memphis, TN, March 2012 (Invited).

39. Jackson, R. E., and R. G. Luttrell. 2012. Resistance events – monitoring, challenges and failures. Entomological Society of America, Member Symposium "*GMOs for IPM – Implications for Field Crops*", Knoxville, Tennessee, November 14, 2012. (invited presentation)

40. Jurat-Fuentes, J. L. M. Adang, and O. P. Perera. 2012. Identification of a biomarker for resistance to genetically engineered insecticidal crops. ISBN News Reports, Virginia Polytechnic University, October 2012.

41. Luttrell, R. G., K. C. Allen, P. O'Leary, and T. G. Teague. 2011. Insect infestations, crop development, and evolving management approaches on a northeast Arkansas cotton farm. Beltwide Cotton Conference, Atlanta, GA.

42. Luttrell, R. G., Maribel Portilla, Gordon Snodgrass, and Ryan Jackson. 2012. Bioassays of Tarnished Plant Bugs (*Lygus lineolaris*) exposed to *Beauveria bassiana*. Joint Meeting of Southeastern and Southwestern Branches, Entomological Society of America, Little Rock, Arkansas.

43. Luttrell, R. G., R. E. Jackson, and K. C. Allen. 2012. Insecticide treated and untreated Bt and conventional cottons under high insect pressure in large field cages. Beltwide Cotton Conference, Orlando, FL.

44. Luttrell, R. G., R. E. Jackson, and K. C. Allen. 2012. Insect control without Bt. Beltwide Cotton Conference, Orlando, FL. (Invited)

45. Luttrell, R. G., R. Jackson, and C. Allen. 2012. Insect control without Bt. Symposium on "*Conventional Cotton – Back to the Future*". Beltwide Cotton Conference, Orlando, FL, January 4, 2012. (Invited)

46. Luttrell, R. G. 2012. What's bugging you? Two Invited One-Hour Lectures to Arkansas Master Gardener State-wide Conference, University of Arkansas, Monticello, May 18, 2012. (Invited)

47. Luttell, R. G., D. A. Adams, L. C. Adams, K. C. Allen, R. E. Jackson, O. P. Perera, M. R. Portilla, G. L. Snodgrass, and Y.C. Zhu. 2012. Student employment in the USDA ARS Southern Insect Management Research Unit: A foundation for scientific inquiry in the Mississippi Delta. Joint Meeting of the Mississippi Entomological Association, Mississippi Weed Science Society, and Mississippi Association Plant Pathology and Nematology, Mississippi State, Mississippi, October 23, 2012.

48. Luttrell, R. G., K. C. Allen, R. E. Jackson, and O.P. Perera. 2012. Deployment of Bt cotton and Bt corn in the agricultural landscape of the southern U.S., opportunities and challenges for strategic resistance management. Entomological Society of America, IRAC U.S. Symposium "*Do Crises Drive Innovation? Resistance Management: Proactive or Reactive*?" Knoxville, Tennessee, November 13, 2012. (Invited)

49. Luttrell, R. G. 2012. Working together as a team. USDA ARS Mid South Area Office Professionals Workshop, Stoneville, Mississippi, November 29, 2012 (Invited)

50. McPherson, W., A. L. Catchot, F. R. Musser, D. R. Cook, and K. C. Allen. 2012. Residual toxicity of selected insecticides to stink bugs. Beltwide Cotton Conference , Orlando, FL. Feb. 4-6, 2012

51. Perera, O. P., G. L. Snodgrass, R. E. Jackson, K. C. Allen, and P. F. O'Leary. 2012. Transcriptom of the tarnished plant bug, Lygus lineolaris with emphasis on digestion related genes. Annual Entomological Society of America, Knoxville, TN. Nov 11-14, 2012.

52. Perera, O. P., Gordon L. Snodgrass, and Patricia F. O'Leary. 2012. Prevalence of the small RNA virus strain LyLV-1 in natural populations of *Lygus lineolaris* in the Mississippi Delta. Beltwide Cotton Conferences on January 5, 2012

53. Portilla, Maribel, Gordon Snodgrass and Randy Luttrell. 2012. Impact of the entomopathogenic fungus *Beauveria bassian*a against *Lygus lineolari*s and non-target insects. Joint Meeting of Southeastern and Southwestern Branches, Entomological Society of America, Little Rock, Arkansas. (Poster)

54. Rashid, T. and L. Adams. 2011. Effect of sweetpotato variety and cultural practices on insect damage. 16th Biennial Research Symposium of 1890 Land-Grant Universities, Association of Research Directors in Atlanta, GA.

55. Snodgrass, G. L. 2011. A summary of 14 years of monitoring for insecticide resistance in tarnished plant bug populations in the Mississippi River Delta. Annual meeting Mississippi Entomological Association, Starkville, MS. (Poster)

56. Snodgrass, G. L. 2012. A comparison of diapauses termination in tarnished plant bugs (Hemiptera: Miridae) from the Mississippi Delta and Springfield, Illinois. Annual Meeting Mississippi Entomological Association, Mississippi State, MS October 2012.

57. Von Kanel, B., A. Catchot, J. Gore, F. Musser, and R. Jackson. 2012. Selectivity of Genuity VT3PRO field corn on cotton bollworm, Helicoverpa zea, populations infesting dual-gene transgenic cotton. . Southeastern Branch Meeting of the Entomol. Soc. of Am. Little Rock, AR, March 2012.

58. Von Kanel, B., A. Catchot, J. Gore, F. Musser, and R. Jackson. 2012. Susceptibility of cotton bollworm, Helicoverpa zea, collected from Genuity VT3PRO field corn on dual-gene transgenic cotton.________. Beltwide Cotton Conf., Orlando, FL, January 2012.

59. Zhu, Yu Cheng and Randy Luttrell. 2012. Comparative study of acephate resistance in the tarnished plant bug: dose response, enzyme activities, sequences, and gene regulation. Joint Meeting of Southeastern and Southwestern Branches, Entomological Society of America, Little Rock, Arkansas. (Poster)

60. Zhu, Y. C., R. Luttrell. 2012. Comparative study of acephate resistance in the tarnished plant bug: dose response, enzyme activities, sequences, and gene regulation. Southeastern and Southwestern Branches Join Meeting March 4-7, 2012.

61. Zhu, Y. C., and R. G. Luttrell. 2012. Potential risk of multiple/cross resistance development to commonly used insecticides in field populations of the tarnished plant bug. Joint Meeting of the Mississippi Entomological Association, Mississippi Weed Science Society, and Mississippi Association Plant Pathology and Nematology, Mississippi State, Mississippi, October 23, 2012.

Appendix A

Notes from Research Discussions
Mississippi Agricultural Consultants Association
USDA ARS Southern Insect Management Research Unit
March 19, 2012
National Biological Control Laboratory Conference Room

Tim Sanders and Virgil King, President and Past-President of the Mississippi Agricultural Consultants Association (MACA), worked with Randy Luttrell, Research Leader of the USDA ARS Southern Insect Management Research Unit (SIMRU) in Stoneville, Mississippi, to organize a research discussion between leadership of the MACA and research scientists in SIMRU. Consultants attending the meeting were Tim Sanders, Virgil King, Bruce Pittman, Jeff North, Joe Townsend, Dee Boykin and Phil McKibben. All Category I (Clint Allen, Ryan Jackson, Randy Luttrell, O.P. Perera, Maribel Portilla, Gordon Snodgrass, Yu Cheng Zhu) and Category III scientists (Donny Adams, Larry Adams) in SIMRU attended and presented brief overviews of their current research. Edgar King, Area Director of the USDA ARS Midsouth Area, and Archie Tucker, Assistant Area Director, joined the group for lunch and discussed ARS research funding and priorities. Chris Johnson, Owen Houston, Cathy Warren, Sakinah Parker, and Phil Powell of SIMRU also attended portions of the morning discussion. Walker Jones, Director of the National Biological Control Laboratory and Research Leader of the Biological Control of Pests Research Unit, participated in the meeting and provided an overview of the research activities in his unit. A copy of the agenda is appended to these notes.

The meeting began at 9 am with introductions and brief summaries of SIMRU's current mission and vision.

> *The mission of the Southern Insect Management Research Unit (SIMRU) is to generate new knowledge of arthropod pest biology, ecology and management and integrate this knowledge into contemporary farming systems that will promote economical and environmentally stable pest management practices for the southern U.S.*
>
> *The vision of SIMRU is to be a recognized center of innovation for negating agricultural pest problem through deployed scientific knowledge of pest biology, ecology and management options.*

Luttrell presented a summary of changing crop acreages in Mississippi and posed a few questions that SIMRU was interested in addressing during the research discussions:

Important Questions Relative to MACA Perspectives

(1) *Given the changing agricultural landscape, what are most critical insect problems facing crop production in the Midsouth?*
(2) *What are the most important research questions that need to be answered to address these problems from immediate and more long-term perspectives?*
(3) *What are the research questions that are best addressed by SIMRU?*

(4) Are their options for expanded collaborations between SIMRU scientists and Mississippi consultants? Data mining, on-farm research, area-wide surveys and management systems.

Ryan Jackson, Gordon Snodgrass and O.P. Perera, Lead Scientists on SIMRUs three major research projects, outlined the projects and described current research and objectives research for each project. All three projects are managed under National Program 304 (Crop Protection and Quarantine).

Insecticide Resistance Management and New Control Strategies for Pests of Corn, Cotton, Sorghum, Soybean, and Sweet Potato
Ryan Jackson (Project Leader, 0.60 FTE), K. C. Allen (0.75 FTE), O. P. Perera (0.4 FTE), Y. C. Zhu (1.0 FTE), G. Snodgrass (0.75 FTE), R. Luttrell (0.3 FTE)

Control of Tarnished Plant Bugs by Biocontrol and Other Methods
G. Snodgrass (Project Leader, 0.25 FTE), R. Luttrell (0.30 FTE), M. Portilla (1.00 FTE)

Effect of Resistance on Insect Pest Management in Transgenic Cotton
O. P. Perera (Project Leader, 0.6 FTE), R. Jackson (0.4 FTE), K. C. Allen (0.25 FTE), R. G. Luttrell (0.4 FTE), Vacant (1.0 FTE)

The remainder of the morning session was devoted to overviews of current research and specific questions from MACA regarding the information presented. A list of the individual researchers making presentations is included in the appended agenda.

Questions/discussion points recorded during these interactions include:

a. Jeff North asked about the value of moth pheromone trap captures and how this information helped individual consultants. SIMRU scientists indicated that there was not a strong correlation or relationship between pheromone trap captures of adults and larval infestations in adjacent cotton. The primary reason of these continuing moth capture studies is overall projects of varying population density from year-to-year and across large geographic regions.

b. Bruce Pittman cautioned against simple generalization of tarnished plant bug populations. He indicated that plant bugs were not the same at all locations in the Delta, and added that differences were not due just to insecticides.

c. Following general discussion of changing agricultural landscape, several MACA members indicated that consulting and effective insect management are not crop specific. Interactions among crops are important and the interplay in populations of insects moving from one crop to another must be considered. An example cited was a general recommendation that cotton should not be planted north of corn because prevailing southern winds tend to increase tarnished plant bug infestations in cotton planted adjacent and north of corn.

d. There were a few questions about the status of *Beauveria* work for control of tarnished plant bug, specifically if SIMRU research was approaching a level where field testing could be done. Snodgrass explained recent tests on cotton and wild hosts, and indicated that additional field testing will occur over the next few years.

Following lunch, the group discussed SIMRU and ARS programs with Ed King and Archie Tucker. Dr. King provided a general overview of recent ARS management issues, including the termination of some ARS research efforts, and an overall assessment of the value and purpose of the research units located in Stoneville, Mississippi. The ~$4.5m budget of SIMRU was discussed as was previous decisions to merge weed and application technology groups into a new Crop Production Research Unit. Consultants were asked if SIMRU was responsive to their needs. Joe Townsend indicated that on several occasions in the past, particularly during periods of Dick Hardee's leadership of the unit, specific concerns of the MACA were addressed by research. He discussed (1) previous doubts by ARS that corn was a host for tarnished plant bugs followed by subsequent ARS research that demonstrated the importance of corn as a host, and (2) Dr. Hardee's willingness to direct research toward monoclonal antibody tests for heliothine species identification as examples of important collaborations. He also indicated that as Chair of the MACA Research and Education Committee he hoped to involve all SIMRU scientists in future MACA discussions of research needs and results. Dr. King thanked MACA for their time and expressed appreciation for their input into ARS research planning.

The discussion topics initiated with Dr. King continued following his departure with a group-wide consideration of research priorities for SIMRU. Luttrell asked the group if SIMRU was over or under-invested in insecticide related research. If the balance of research among cotton, corn and soybean was appropriate, and how the federal research programs of SIMRU integrated research with sister programs in the universities?

A number of different discussion points resulted:

(a) The consultants generally agreed that research efforts between ARS and universities were appropriate and that cooperation and coordination should continue. No clear lines of delineation were suggested.

(b) Additional questions about the sources of funding for SIMRU were asked. Luttrell commented that funding for SIMRU was federal tax-payer investments in the mission of the Unit. While ARS scientists work with universities, industry groups and other scientific organizations on a number of projects and participate in competitive grants, base funding is for the mission of the unit. It is an expectation that the mission and the overall activities address relevant problems.

(c) The group indicated that research in SIMRU appears to be oriented toward cotton insect problems, and that perhaps stronger research efforts in other crops should be considered. They also recognized the historical importance of cotton insect management to the agricultural production system of the Delta. Most of the serious pest problems are not crop specific.

(d) The group expressed strong concern for the widespread deployment of Bt toxins in corn. They questioned the rationale and need for the stacked Bt genes in hybrids grown in the South, and they were concerned about potential resistance management programs targeted for corn rootworm that might be automatically imposed on southern farmers. They asked if these insecticidal traits were necessary in corn grown in the South.

(e) A balance of short- versus long-term research was advised, but the consultants also emphasized the need for relevance and help in dealing with current problems. A concern was expressed for new control options when resistance destroys current technologies (What is the next solution?). The group complimented research like Clint Allen's discussion of reduced plant bug fecundity in soybean (low survival of early instar tarnished plant bug nymphs). They indicated that availability and access to this type of information was important. They recommended more web posting of research results.

(f) Two of the consultants discussed research by Jeff Willers of the ARS group at Mississippi State as an area of potential creativity and additional work. The references were primarily oriented toward sample information and the possible use of sticky cards and productivity zones as guides for sampling intensity. Potential development of new decision criteria was suggested, and opportunities for collaboration were suggested as potential new activities.

(g) The broader impacts of new insecticides, like novaluron, on target and non-target species was discussed. A few of the consultants had observed impacts of Diamond applications on bollworm populations. This led to a brief discussion of increased bollworm problems, especially those in early-production-system soybean. Luttrell asked about possible collaborations with consultants in on-farm research of the soybean insect problems, possibly comparisons of treated and untreated field-level infestations similar to current work comparing conventional and Bt cotton systems. The consultants responded with a number of suggestions. They indicated that they were open to collaborative activities, but reminded the ARS group of the complications of doing research on a production farm, including the need to avoid impacts on farming practices and being sure that data were recorded in a manner suitable for the experiments. They also questioned the need to include untreated comparisons citing additional complications with grower cooperation and arranging field plots that would be isolated from spray drift.

(h) The group briefly discussed the possibility of data mining activities, statistical studies of farmer and consultant records similar to some of the data analyses previously conducted by Luttrell and colleagues on Arkansas databases or even more elaborate data descriptions. The consultants, individually and collectively, have access to years of information that could provide important information on temporal and spatial patterns of pest populations and impacts of pests on resulting yield. Several of the consultants were open to idea and suggested that this may a real possibility of new research.

(l) Walker Jones described work in NBCL including mass production of *Lygus*, work on non-pathogenic strains of aspergillus, microbial control of weeks and the focus of NBCL activities on industry collaborations and biological control of invasive species. He mentioned recent interest in the kudzu bug, the red banded stink bug, and the brown marmorated stink bug as examples.

The meeting concluded about 3:30 pm. Luttrell and the SIMRU scientists expressed appreciation to the MACA for taking time to discuss research, and the MACA expressed their appreciation of the opportunity to renew and strengthen communications. Walker Jones gave several of the consultants a tour of the NBCL facility.

AGENDA
Research Discussions
Mississippi Agricultural Consultants Association
USDA ARS Southern Insect Management Research Unit
March 19, 2012
National Biological Control Laboratory Conference Room

9:00 am	**Introductions, Welcome, Purpose of Meeting**
9:30 am	**Overview of SIMRU Research Structure and Projects** SIMRU Mission, Vision and National Program (Luttrell) IPM/IRM Research Project (Jackson) Bt Resistance Project (Perera) Alternative TPB Management Project (Snodgrass) General Discussion of Research Structure
10:00-10:15 am	**Break**
10:15-11:00 am	**Overview of Individual Research** L. Adams – Sweetpotato Research C. Allen – Soybean/Cotton Insects R. Jackson – Cotton Insects/Resistance Management D. Adams – On-farm Field Studies R. Luttrell – Cotton Insects/Beauveria/Bt Resistance O. Perera – Bt Resistance/ TPB Genetics M. Portilla – TPB and Beauveria G. Snodgrass – TPB Resistance/Beauveria Y. Zhu – TPB Resistance/Sugarcane Borer Bt Resistance
11:00 am – 11:45 am	**Group Discussions/Questions Regarding Current Research**
12:00 noon 1:00 pm	**Lunch with ARS Administration and SIMRU Scientists**
1:00 pm – 3:00 pm	**Discussions/Suggestions for Future Research/Collaborations** Changing Agricultural Landscape – Needed Research Priorities for ARS Cooperative On-Farm Research
3:00 – 3:15 pm	**Break**
3:15 pm – 4:00 pm	**Review Meeting Notes and Openly Discuss Future Communications with SIMRU Research Leader – Tour SIMRU Research Facilities**

Appendix B

Notes from Research Discussions – April 12, 2012
Cotton Incorporated, National Corn Growers Association, National Cotton Council, United Soybean Board and USDA ARS Southern Insect Management Research Unit
National Biological Control Laboratory Conference Room, Stoneville, Mississippi

Scientists in the USDA ARS Southern Insect Management Research Unit 9SIMRU) met with research directors from Cotton Incorporated (Pat O'Leary and Ryan Kurtz), National Corn Growers Association (Rick Vierling), National Cotton Council (Don Parker) and United Soybean Board (Steve Muench) on Thursday, April 12, 2012 to review current research and discuss future research needs associated with insect pest problems of southern crops. All scientists in SIMRU (D. Adams, L. Adams, C. Allen, R. Jackson, R. Luttrell, O. Perera, M. Portilla, G. Snodgrass, Y. Zhu) participated in the meeting and provided brief summaries of their research activities. A copy of the agenda for the meeting is appended to these notes. Commodity research directors were provided with a copy of the 2011 SIMRU Annual Report (available at http://www.ars.usda.gov/SP2UserFiles/Place/64021000/2011%20SIMRU%20Annual%20Report.pdf); estimated insect losses for corn, cotton, and soybean (pdf copies appended to this report); Mississippi State University planning budgets for corn, cotton, and soybean (pdf copies appended to this report); and a pdf handout of the slide presentations describing current SIMRU research (pdf copy appended to this report). Presentations by SIMRU scientists and each commodity research director were made in the morning session. Afternoon discussions emphasized research needs and future priorities. Walker Jones, Director of the National Biological Control Laboratory and Research Leader of the Biological Control of Pests Research Unit; Brian Scheffler, Research Leader of the Genomics and Bioinformatics Research Unit; Tommy Valco, Technology Transfer Coordinator for the Midsouth Area; and Carlean Horton, Administrative Officer at the Jamie Whitten Delta States Research Center, attended the meeting and interacted with the group.

The meeting began at 9 am with brief introductions, an overview of the purpose of the meeting, a brief history of SIMRU, and a statement of SIMRUs research mission.

> *To generate new knowledge of arthropod pest biology, ecology, and management, and integrate this knowledge into contemporary farming systems that will promote economical and environmentally stable pest management practices for the southern U.S.*

Lead scientists for each of SIMRUs major research projects (Ryan Jackson, Project 6402-22000-045-00D, *Insecticide Resistance Management and New Control Strategies for Pests of Corn, Cotton, Sorghum, Soybean, and Sweetpotato*; O. P. Perera, Project 6402-22000-047-00D, *Effect of Resistance on Insect Pest Management in Transgenic Cotton*; and Gordon Snodgrass, Project 6402-22000-044-00D, *Control of Tarnished Plant Bugs by Biocontrol and Other Methods*) provided brief overviews and statements of research objectives currently being addressed. This was followed by brief overviews of each individual research program managed by each of the nine Category I and Category III scientists in the Unit. Luttrell explained that SIMRU also has budget capacity for two to three Category II scientists, and that efforts to hire an insect ecologist in 2011 were impacted by the Agency decision to freeze all open positions. SIMRU has one additional Category I scientist, Beverly Wiltz, from the previous Formosan Subterranean Termite Research Unit in New Orleans that will be joining the Unit in June.

Following the research summaries from SIMRU scientists, each of the commodity research directors provided an overview of their research responsibilities and their current priorities for research.

Pat O'Leary – Cotton Incorporated

Dr. O'Leary introduced Dr. Ryan Kurtz as a new director of Cotton Incorporated research and provided an overview of the 2012 research program objectives. Total funding for 2012 research is $10.28M with $7.693M associated with Strategic Objective 1: *Increase short term profitability* (add value to cottonseed and other byproducts, tools and techniques to increase efficiency). Strategic Objective 2: *Increase long term profitability* (variety improvement) is funded at $1.625M, and Strategic Objective 3: *Increase number of future scientists* (Cotton Incorporated Fellowship Program) is funded at $0.48M. Strategic Objective 4: *Improve sustainability and reputation of U.S cotton production* receives $0.45M in the 2012 budget.

- Results of a 2011 Cotton Incorporated Producer Priority Survey identified five priority concerns in all regions of the U.S. Cotton Belt, although relative ranking varied by region. The top ranked producer issues across the U.S. were: (1) cotton input costs, (2) herbicide resistant weeds, (3) variety selection, (4) cotton's tolerance to heat and drought, (5) early season weed control, and (6) seedling vigor, cottonseed value and plant bug control. In the Midsouth, the top issues (in order of most important) were: (1) herbicide resistant weeds, (2) cotton input costs, (3) variety selection, (4) weed control – early, (5) plant bug control, (6) lack of new crop protection products, (7) cotton's tolerance to heat and drought, (8) soil sampling and analysis for fertilizers, (9)monitoring cottons growth, (10) weed control – late, (11) insecticide resistant pests, (12) cottonseed value, (13) P, K, micronutrient fertilizer applications, and (14) harvest aid materials and timing. The survey was administered to 10,500 growers that sold a minimum of 100 bales of cotton. A total of 885 usable surveys (8-9% representing ~ 10% of U.S. acreage) were used in the final analysis.

- Dr. O'Leary further elaborated on tarnished plant bug control indicated that topics of resistant/tolerant varieties, novel management strategies, resistance management, and management across the farmscape were issues of research interest. Issues related to Bt cotton included resistance management in bollworm and fall armyworm, and procedures for managing bollworm in Bt cotton. Insect management priorities in the Midsouth also include concerns for insecticide resistance in bollworm to pyrethroids and resistance in cotton aphid to neonicotinoids. There is a growing concern for regulatory action associated with pollinators (honey bees and native bee species).

Dr. O'Leary's presentation resulted in dialogue about pollinator protection, especially the concern for cotton because of the prolonged period of flowering and the presence of extra-floral necatories, Bt resistance issues, possible collaboration with plant breeders, and novel ways to manage tarnished plant bug.

- Ryan Kurtz presented a slide showing the overlap of cry proteins between transgenic cotton and transgenic corn (Cry1Ac and Cry2Ae are unique to cotton, Cry1A.105 is unique to corn, cotton and corn share Cry1Ab, Cry1F, Cry2Ab, and Vip3A). The complexity of managing resistance and problems associated with measurements of changing insect susceptibility was discussed.
- Brian Scheffler mentioned research being conducted by national collaborators working on cotton genetics and the possibility of associating insect resistance traits with the total genomics research. Don Parker indicated that the Cotton Industry was interested in nectariless traits because of the recent concern with pollinators and associated impacts on insecticide regulations.

- Yu Cheng Zhu advocated research to look at novel ways to managing tarnished plant bug through targeted disruption of metabolic/physiological pathways (i.e. RNAi approach).

Richard Vierling – National Corn Growers Association

Dr. Vierling provided an overview of the National Corn Growers Association, its organizational structure and networking across the U.S. Corn Belt. He indicated that he was unsure about his role in the discussions because of the relatively low interest among corn farmers in insect management issues. In a general way, most corn farmers look to biotech groups and industry to address insect management issues, primarily through seed treatments and transgenic traits. Some groups suggested that by 2020 there will 20 transgenes in corn. Luttrell acknowledged the concern and the previous emphasis of SIMRU research on cotton and soybean insects, but assured the group and Dr. Vierling that involvement of National Corn Growers and/or other corn interest groups was critical in the research discussions because of the changing agricultural landscape in the South. Corn is very important in the landscape of the Delta, and corn significantly influences major pests in the regions. Dr. Vierling's presence and involvement at this particular meeting was highly valued.

- Dr. Vierling discussed plant genome research and the central role of corn in this process. In 2012, he expected 6 billion SNPs to be added to the maize database. He indicated involvement of the NCGA with NP-301 and interest of NCGA in maintaining a definable maize database.
- Ethanol is a research priority, but the amount of ethanol that can be used as fuel is limited (not more than 15 billion gallons) and NCGA is interested in developing other uses for corn and corn products.
- NCGA is involved in the law suit associated with agricultural run-off in Chesapeake Bay, and N use and environmental impacts are major topics of research interest. Product stewardship and sustainability are important topics for corn growers. Nitrous oxide omission is a major interest area, especially monitoring procedures that could potentially impact all crops.
- NCGA is also actively involved with small startup companies, and there is a major interest in myco-toxin production and stewardship of corn products.
- Insect control issues are largely influenced by priorities in the Midwest (Iowa, Indiana, Illinois). Acreage in the South is a small component of overall corn acreage. Potential planting of corn on vast acreages in the West could dramatically mask any increased acreages in the South.

Don Parker asked about sugarcane borer, Southwestern corn borer and Eurorpean corn borer abundance in the Delta and commented that his previous work in Mississippi had identified only a few infestations of sugarcane borer in the South Delta. Infestations of European corn borer appeared to be patchy and perhaps associated with localized production practices. Ryan Jackson and Clint Allen indicated that recent surveys by Don Cook and the Mississippi State group had similar conclusions.

Don Parker – National Cotton Council

The pollinator issues (i.e. suggested impacts of neonicotinoid insecticides on pollinators) and associated concerns for insecticide regulations were of primary concern for Dr. Parker and the National Cotton Council. He described the problem and concerns for pesticide registrations suggesting that current information is limited. He indicated that new information on bee foraging and ecology in cotton was needed and that it is difficult to manage the growing concerns for pesticide use because of limited ecological background information.

- He suggested that SIMRU could have a role in understanding the prevalence and interaction of cotton with honey bees. He also suggested that the Mississippi Delta could be an ideal study site because of the abundance of crops, diverse landscape and intense agricultural management. Interactions with ARS groups in Louisiana was suggested as a possibility in addressing research needs. He indicated that Mississippi State University had just hired a new scientist with pollinator expertise.
- Dr. Parker discussed concerns for Bt resistance and the uncertainty of how to measure and confirm resistance. He indicated that discussions should be broader than cotton and that soybean and corn have major interest in the question. He suggested that SIMRU might have a role in organizing a national discussion of what resistance means at the field level. Mitigation procedures and future regulatory actions will require a more defined process.
- Dr. Parker also asked about reports of increased problems with bollworm in soybean and suggestions of higher cotton yields associated with sprays of Coragen/Prevathon in situations with low insect densities.
- He asked about the activity of the NI8 strain of *Beauveria bassiana* and how it compared to previous commercial products like Naturalis.

Bt resistance was discussed by the group including Don Parker's suggestion for more dialogue. Dr. Muench indicated that the United Soybean Board would look to university and ARS scientists to provide advice on the subject. In regard to the establishment of resistance guidelines or definitions of resistance, both agreed that ARS would be preferred to EPA determining scientific decision points for remediation or resistance confirmation. Dr. Kurtz further explained the complexity of the scope of Bt proteins shared by biotech companies and the interactions among crops. He also describe the proactive action of the EPA in regard to the Bt resistance issue in corn and suggested that the insect group could benefit from the example of managing herbicide resistance. The difference between weed and insect resistance from this perspective is that insect resistance had a regulatory trigger associated with documentation, weed resistance does not. Dr. Vierling asked about the role of professional societies citing leadership in the Weed Science Society of America for the herbicide resistance management approach. The group also discussed problems with proprietary control of the toxins/proteins expressed in transgenic plants and associated impacts on clear experimental documentation of resistance. The group discussed compliance and growing influence of compliance on management options like "refuge in a bag". Dr. Vierling asked about the potential role of "refuge in a bag" in the South. Luttrell indicated that he had a concern for insect movement and the potential utility of the approach. Others agreed, but also noted that much was unknown about many of the insect resistance traits. A discussion of the need to understand resistance mechanisms continued, and it was noted that polygenic traits are much more difficult to understand and manage than single, major gene resistance events. Dr. Kurtz reminded the group of the influence of patent protection on the process, and a discussion of recent agreements between public entomologists and biotech companies highlighted a need to further resolve the role of ARS in these issues.

Regarding the question of increased populations of bollworm in soybean, Luttrell indicated that research was being considered in SIMRU to empirically measure these suggested changes.

Maribel Portilla addressed the question about *B. bassiana* and NI8 indicating that the NI8 strain was 10X more active against *L. lineolaris* that previous commercial strains. Gordon Snodgrass added that cotton may not be the idea target for use of NI8 and that SIMRU research was looking at other potential weak links in the seasonal history of the bug as potential targets.

Steve Muench – United Soybean Board

Dr. Muench provided an overview of the soybean check off program and the structure of the United Soybean Board that includes Communications, Domestic Marketing, New Uses, Production, and a combination of International Marketing and Global Opportunities. In Production Research, the FY12 investment included \$13M in yield, \$4.4M in composition, and \$1M in research coordination. Composition Research included \$1.85M in oil (genomics, biotech, breeding), \$1.62M in protein (genomics, biotech, breeding), \$0.41M in composition survey, and \$0.38 in measurement techniques. The research investment in Yield Research was distributed with \$7.72M in breeding and management, \$4.22M in disease research, and \$3.07M in soybean cyst nematode research (the dominant pest question for soybean). Breeding/Management Research included \$2.63M in functional genomics, \$1.58M in yield, \$1.64M in drought/flooding, \$0.91M in insect resistance, and \$0.76M in cropping systems.

- Insect Resistance Research included \$0.545M for stink bug/kudzu bug research and \$0.365 for soybean aphid research. The \$545,000 grant for stink bug resistance research in FY12 included: (a) screening soybean germplasm collection for resistance to red-banded stink bug, (b) biology, distribution, and management of brown marmorated stink bug, (c) distribution, pest status, and controls strategies for red-banded stink bug, and (d) management of kudzu bug/bean plastacid. Clint Allen of SIMRU is actively involved in the project administered through Texas A&M University.
- Dr. Muench further described the check-off process and the large influence of within state funding of projects. FY13 funding appears to be \$70.3M with \$14.76M for production. A new action team will be appointed in December 2012 to develop a FY14 budget during the spring-summer of 2013. He also described the management arrangement of SmithBucklin and the new USB organization structure with Action Teams and Target Area Working Groups. Key issues include: (a) funding will be allocated to Action Teams, (b) Target Area Working Groups will liaise with industry and work across Action Teams, (c) Action Teams will appoint members to Working Groups as appropriate, and (d) ultimate USB will move to fewer, larger projects.
- Supply Action Areas for Composition will include: (a) improve oil (reduce linolenic acid, increase oleic acid, reduce saturated fatty acids), (b) increase oil without loss of protein, (c) increase protein without loss of oil (improve digestible amino acids and AA balance), and (d) increase digestible sugars (improve metabolizable energy content of meal).
- Supply Action Areas of Yield will include (a) resistance (drought/flooding, SCN and other nematodes, SDS, charcoal rot, *Phomopis* seed decay, *Phyophthora*, soybean rust, soybean aphids and stink bugs). The stink bug investment appears to be the dominant insect research need for the southern U.S.
- Overall, USB is developing a long-range strategic plan and USB will be reorganized with USB's Strategic Objectives. Funding priorities will shift as well.

Don Parker indicated that cotton groups are also aware of kudzu bugs and that potential quarantines of exports is an issue. Additional dialogue dealt with the nature of policy versus research issues. Steve Muench indicated that his responsibilities were limited to research issues. Parker acknowledged and explained that he and Pat O'Leary share different responsibilities with Cotton Incorporated focused on research. The Cotton Council deals with the total spectrum of issues ranging from specific research needs, but many of the issues relate directly to policy issues.

Following the overview of commodity research directions and the earlier summaries of current research with SIMRU, the group considered additional issues related to future research needs. Items discussed and recorded include:

- Luttrell asked about interest and activities in Bt soybean. Muench responded that several researchers in the U.S. were involved, and biotech groups had investments in the technology. Major interest in use of Bt soybean and the need for insect control did not appear to support significant interest in the U.S. There may be more interest in South America, and expanded market portfolio with comparable investments for product development in international markets could bring the product to the U.S. Regulatory questions would be an issue. O'Leary indicated that the market would have to be large enough to support product development and registration.
- Luttrell also asked if SIMRU was over or under invested in "resistance" research. The group indicated that resistance was an important topic from their perspective.
- Additional discussion of "refuge in the bag" and regulatory requirements for Bt crops highlighted the complexity of multiple crops and numerous transgenic products. Kurtz suggested that creativity in resistance monitoring or rating severity of insect damage may have potential for more effective use of transgenic traits. He cited the rating scale used in corn as an example that allow growers to evaluate insect survival and severity of feeding rather than a "yes or no" categorization of product performance. The Bt resistance issues and regulatory actions associated with transgenic plants and insect resistance appear to support multiple commodity discussions.
- The group briefly discussed opportunities for collaborative research across the commodity group. Remediation of insect resistance, stink bug problems in the major crops, concerns for insecticide impacts on pollinators, and a system-wide assessment of insect pest problems were possible topics.
- Limited discussion of approaches to research management occurred. Having an appreciation of value (i.e. in development of tools or technologies) at the start of a projects was offered as approach to better manage research funds. Having usable benchmark information is important in this process.
- O'Leary encouraged continued emphasis on tarnished plant bug research and suggested that creative new approaches would be appropriate. Zhu advocated work on RNAi and novel approaches to tarnished plant bug control. Parker asked about interactions with other ARS laboratories. Luttrell indicated that Perera's work with the ARS group in Arizona was an example of collaboration. Perera briefly described work with colleagues in Arizona directed at odorant proteins and possible regulation of chemical ecology.
- Interest in nectariless cotton and the possible advantages of nectariless cotton relative to pollinator issue was expressed. Luttrell asked about broader work in Host Plant Resistance (HPR) for insects. Scheffler added that opportunities to look for insect resistance in cotton and

soybean genetic materials are much improved given the genetic work underway with both crops. Paul Williams' work with corn and HPR traits was discussed and options to better link NP301 and NP304 efforts was mentioned.

- The group briefly discussed seed treatments and the widespread use of seed treatments as a mechanism to control insects. Commodity groups depend upon seed treatments and transgenes to deliver insect control technologies. Costs of seeds reflect this bundling of technologies.

Following expressions of appreciation by SIMRU, Cotton Incorporated, National Corn Growers, National Cotton Council, and the United Soybean Board, the meeting was adjourned at 3:30 pm.

AGENDA
Research Discussions – April 12, 2012
Cotton Incorporated, National Corn Growers Association, National Cotton Council, United Soybean Board, and USDA ARS Southern Insect Management Research Unit
National Biological Control Laboratory Conference Room, Stoneville, Mississippi

9:00 am	**Introductions, Welcome, Purpose of Meeting**
9:15 am	**Overview of SIMRU Research Structure and Projects**
	SIMRU Mission, Vision and National Program (Luttrell)
	IPM/IRM Research Project (Jackson)
	Bt Resistance Project (Perera)
	Alternative TPB Management Project (Snodgrass)
	Overview of Individual Research
	L. Adams – Sweetpotato/Corn Research
	C. Allen – Soybean/Cotton and Corn Insects
	R. Jackson – Cotton and Corn Insects/Resistance Management
	D. Adams – On-farm Field Studies
	R. Luttrell – Cotton and Corn Insects/*Beauveria*/Bt Resistance
	O. Perera – Bt Resistance/ TPB Genetics
	M. Portilla – TPB and *Beauveria*
	G. Snodgrass – TPB Resistance/*Beauveria*
	Y. Zhu – TPB Resistance/Sugarcane Borer Bt Resistance
10:30 am	**Break**
10:45 am	**Overview of Commodity Group Research Priorities**
	Cotton Incorporated – Pat O'Leary, Ryan Kurtz
	National Corn Growers Association – Richard Vierling
	National Cotton Council – Don Parker
	United Soybean Board – Steve Muench
12:00 noon	**Lunch with Commodity Group Representatives, ARS Administration, Delta Council Representation, SIMRU Scientists --**
1:00 pm – 3:30 pm	**Discussions/Suggestions for Future Research/Collaborations**
	Changing Agricultural Landscape – Needed Cross-Commodity Research
	Priorities for ARS – Corn, Cotton, Soybean Insect Management
	Resistance Management/Regulatory Issues
	Short- versus Long-Term Insect Management Research
3:30 pm	**Continued Informal Discussion and Departure for Greenville Regional Airport**
	Owen Houston and Phil Powell Assist Visitors with Airport Connections

Appendix C

Final Notes -- Research Discussions –May 2, 2012
USDA ARS National Program Staff and Southern Insect Management Research Unit
National Biological Control Laboratory Conference Room, Stoneville, Mississippi

Discussions began at 9 am in the conference room of the National Biological Control Laboratory. National Program Leaders in attendance were Deb Fravel, Roy Scott, and Dan Strickman. Scientists from the Southern Insect Management Research Unit (SIMRU) included Donny Adams, Larry Adams, Clint Allen, Ryan Jackson, Randy Luttrell, O.P. Perera, Maribel Portilla, Gordon Snodgrass, and Yu Cheng Zhu. Beverly Wiltz, a scientist in the process of relocating to SIMRU from the former Formosan Subterranean Termite Research Unit in New Orleans, also attended the research discussions. Ed King, Area Director, and Tommy Valco, Technology Transfer Coordinator, participated in the meeting. Cathy Warren, Sakinah Parker, and Yolanda Harvey, SIMRU administrative staff, assisted with meeting logistics, computer equipment, and arrangements for lunch.

An agenda and a pdf handout of the slide presentations were distributed. Copies of both are appended to these notes. National Program Leaders were also given a copy of the 2011 Annual Report for SIMRU, a bound copy of resumes of current SIMRU scientists, and copies of notes from previous meetings with the Mississippi Agricultural Consultants Association and major crop commodity representatives.

Following individual introductions and an overview of SIMRU history and changing crop landscape in the Mississippi Delta, Lead Scientists for each of three major research projects in the Unit gave brief overviews of the projects including a summary of research objectives and current activities. This was followed by short summaries of current research by each scientist. Discussions recorded during this review of individual research included:

L. Adams Presentation

- Dan Strickman asked about acreages of sweetpotato. Larry did not have exact numbers, but indicated that acreage was low as compared to the major row crops (Mississippi has about 20,000 acres of sweetpotato compared to 740,000 acres of corn, 605,000 acres of cotton, and 1,800,000 acres of soybean). A new processing plant in Delhi, Louisiana is creating additional interest. Randy Luttrell commented that a major focus of previous research was management systems for small farmers in the Mississippi Delta. Research needs of these small farmers are quite different from those of large production farms, and needed research is often impacted by communication networks. Luttrell indicated that SIMRU was starting efforts to work directly with a group of small farmers this year. This was further discussed by the group. Roy Scott and Deb Fravel indicated that these types of projects could be important impact stories for the Agency, and they encouragedd careful attention to the writing of impact statements.
- Deb Fravel also asked about nematodes. Larry indicated that nematode control had been the most significant benefit of pest control in his studies in Mississippi. Wireworms represent the most important arthropod pest problem.

C. Allen Presentation

- Dan Strickman indicated that this was the first discussion he had heard from the group on stink bugs. He was curious about the current status of stink bug problems, biological control effects and general activities on stink bug management. Clint indicated that there was strong interest in studying red banded stink bug (*Piezodorus guildinii)*, but much of the economic damage in soybean is still associated with the complex of green, southern green and brown stink bugs on soybean. While there is interest in biological control of a number of invasive species (brown marmorated stink bug, kudzu bug) and Walker Jones is involved with biological control agents in the Quarantine

Facility, most stink bug control on soybean relies on insecticides. This has had a significant impact on soybean production, and one or two applications of insecticide for stink bug control are common.

- Clint also discussed his work with the United Soybean Board and a group of entomologists across the southern U.S. to evaluate soybean germplasm for possible stink bug resistance.
- Dan Strickman inquired about the use of pollen as a marker of stink bug dispersal, and specifically asked if pollen was ingested by tarnished plant bugs. Clint indicated that pollen had been found inside the digestive tract of plant bugs and that this was an issue being studied.

<u>R. Jackson Presentation</u>

- Roy Scott and Dan Strickman inquired about the procedures used to separate pigweed from the C4 grasses using the stable isotope analyses described by Ryan. He explained that differences between pigweed and corn were determined on the basis of N isotope analyses.
- Additional discussion of the potential use of the C and N isotope analysis versus the use of pollen as a marker of insect dispersal resulted. The isotope approach appears to be more accurate, but it targets adults resulting from immatures that feed on the different hosts (i.e. generation movement). Clint indicated that pollen could be used to track adult movement.

<u>D. Adams Presentation</u>

- Roy Scott asked if Monsanto or other biotech groups had expressed interest or concern for the studies comparing transgenic insect controls to non-transgenics and oversprays of insecticide. Donny and Ryan indicated that the groups were well aware of this research and that similar work was underway with a number of university groups. The on-farm research allows SIMRU to examine probability of need of insect control, a topic that could be of concern for biotech groups marketing the transgenic seeds.
- Deb Fravel commented that the economic analyses were important aspects of reporting. Luttrell indicated that a valuable component of this team research was Clint Allen's training as an agricultural economist (as well as his training as an entomologist). His work with Donny and Ryan was providing useful information about the value of insect control in systems experiencing rising production costs.
- Ryan Jackson further explained the options created by new insecticides (ie rynaxypry) that provide longer residual control of bollworms. This may provide realistic opportunities or options to control pest currently targeted by transgenics. Cotton may be protected for multiple weeks from a single application of these new insecticides. Another important component of the research was the availability of new cotton lines from public breeding programs (F. Bourland, University of Arkansas; B. Meredith, USDA ARS Stoneville) that were high yielding and had comparable yield potential in the absence of insects.
- Dan Strickman also asked if fuel costs were important cost considerations. The group acknowledged that the number of trips a farmer makes across a production field is important given efficiency of large scale production. Many insecticide applications are made by aerial sprays that cost ~$5/acre. While these costs are important, the group did not consider this to be driving force in the profitability. Clint Allen explained that these costs were included in the economic analyses of the different insect management strategies.

<u>R. Luttrell Presentation</u>

- Randy Luttrell indicated that he tried to balance his research time across the three Unit projects. He was appreciative of the other scientists allowing him the opportunity.
- Dan Strickman asked about self-perpetuation of *Beauveria* in the field. Luttrell indicated that he thought that very little *Beauveria* remained over time in sprayed cotton, but that natural infections of tarnished plant bug were common. He referred to Gordon Snodgrass and Maribel Portilla who

explained that the use of *Beauveria* on other host plants, targeted weed hosts, could result in vertical transmission of the entomopathogenic fungus.

O. P. Perera Presentation

- Roy Scott complimented O.P. on his approach to studying genetic structure of resistance in insects. He also asked if O.P. was looking at the genetics of plant response. O.P. responded that his work currently focused on insect genetics but that the building blocks would be important for the type of work Scott was referencing. He further explained his recent training and interactions with Ed Buckler's ARS group and Cornell's Institute for Genomic Diversity on genotyping-by-sequencing approaches, and his recent involvement with Sharon E. Mitchell, of the same research group, on *Lygus* genome assembly. Roy Scott stated that this was the correct approach and briefly mentioned that he has similar discussions with the Maricopa group working with *Lygus herperus*.

M. Portilla Presentation

- Dan Strickman was interested in the information presented showing differential susceptibility of the non-target organisms, especially spiders. He asked if the differences were associated with contact or activity given contact. Maribel explained that her treatment procedures provide high levels of contact and the results reflect differential susceptibilities given contact. Additional discussion followed about the potential activity of *Beauveria* against spiders, the types of spiders assayed in Maribel's laboratory studies (jumping and crab spiders, Salticidae and Thomisidae, respectively) and the activity on spiders in the field (mostly likely green lynx spiders (Oxyopidae in cotton)). Maribel indicated that some infection could occur from predator consumption of infected prey.
- Additional discussion of Maribel's work with non-target impacts of *Beauveria* included the targeted use of *Beauveria* for control of diapausing tarnished plant bug on fall overwintering hosts and the importance of collecting non-target information on the broad spectrum entomopathogen.

G. Snodgrass Presentation

- Gordon described feeding behavior of tarnished plant bug in response to a question from Dan Strickman regarding the pharyngeal pump in bugs as possibility related to those in mosquitoes. Strickman indicated that new work was being done at an ARS Laboratory in Texas on the basic biology and mechanisms of mosquito feeding.
- Dan Strickman commented that he appreciated studies of basic biology of insects. Luttrell added that Gordon's program was a very unique example of long-term commitment to understanding the biology and ecology of a single species. This information would likely be the foundation for future advances in managing the pest.

Y. C. Zhu Presentation

- Roy Scott asked if Yu Cheng was collaborating with the Maricopa group. He indicated that he had informal discussions and went to school with Jeff Fabrick, but that he had no formal research currently with the group. Luttrell added that we would later summarize collaborative relationships for SIMRU scientists.
- Luttrell also added that Yu Cheng had strong contacts with Nanjing Agricultural University and the Chinese Academy of Agricultural Sciences. This led to additional discussions of growing relationships between ARS and the Chinese Academy of Agricultural Sciences including the possibility of a Chinese research laboratory in the United States.

Following the summaries of individual research projects, the group reviewed current cooperative agreements and developing collaborations. They are listed on the slide handout. Roy Scott and Deb Fravel discussed the importance of accountability with the cooperative agreements and that this was a growing concern for management of national programs. Luttrell indicated that he, Ryan Jackson, and Clint Allen had been actively working with existing scientists at Alcorn University, Mississippi State

University and the Delta Research and Extension Center to strengthen partnerships and focus research on common goals. Growing relationships with other groups, for example O.P. Perera work with the Cornell group on genome assembly, Maribel Portilla and Gordon Snodgrass' negotiations for use of a tarnished plant bug bioassay diet system, and Ryan Jackson's developing work with Monsanto to study tarnished plant bug resistance to transgenic proteins, are more strongly emphasizing Unit mission and defined research goals. Luttrell emphasized that the strong working relationships with Mississippi State University and Alcorn State University were critical to the research capacity of the Unit.

During lunch, Luttrell showed a brief video of 2011 STEP students presenting oral summaries of their learning experiences in SIMRU. He explained that SIMRU annually hires more than 25 part-time student employees. In 2011, the Unit developed a new system for recruiting, interviewing, and mentoring students. This included a two-tiered selection process based on written applications and oral interviews of finalists, and required written and oral presentations of their learning experiences at the end-of-the-summer. Videos from the 2011 STEP presentations are posted on the SIMRU website. The Unit is currently interviewing and hiring 2012 STEP employees.

Afternoon discussions emphasized "*what the Unit should be doing*" as compared to the morning reports of "*what the Unit is currently doing*". Luttrell asked the NPLs for advice and specific suggestions for SIMRUs future research programs. Roy Scott responded that it appeared that the Unit was following appropriate procedures, working with key clientele groups, and beginning to build information for future five-year programs. Deb Fravel indicated that she had learned more about the insect group during the morning discussions. She advised the group to think about specific goals, what should be accomplished and then work backwards to develop the specifics. She strongly advised the group to consider impact and use measurable statements in the development of future research plans. She indicated that objectives of projects should be more broadly stated and that sub-objectives should be more specific. The objectives and overall statements should not limit research creativity.

Luttrell further asked about short and long term planning and how a Units total portfolio of research should be organized. He specifically asked about the wisdom of a unit working under one or multiple national programs. Scott and Fravel responded that National Programs are important organizational umbrellas and that most programs are predominantly defined under a single program. However, this is not intended to discourage cross linkages with other National Programs. Roy Scott again emphasized his interest in seeing the pest management groups work closer with the crop breeding groups. His effort to organize dialogue among the pest disciplines and cotton breeders at the Beltwide Cotton Conference is an example of these expanding collaborations.

The group then discussed procedures for developing projects in NP 304. Luttrell provided a brief history of SIMRUs recent experiences in writing SIMRUs three major projects during a period with three vacancies of the eight total Category I scientist positions. He expressed appreciation for the group's ability to organize and finalize the project, but also wanted to discuss some of the problems in setting new priorities and flexibility in approaches to define content and purpose of new projects. Luttrell asked Ryan Jackson to express some of his concerns about the current structure of the projects and possible overlap of research objectives from one project to another. Jackson suggested that a structure based on the target pest (i.e. a *Lygus* project, a heliothine project, etc.) might be more logical. Roy Scott and Deb Fravel both responded and offered the following points as guidance in developing new projects:

- New projects should be written with an appreciation for the 5-year time frame involved.

- National programs (and new projects) need to address stakeholder interests and the support base that works with Congress to obtain support for our work. Thus, commodity accountability is important in the process.
- The process for writing National Programs varies. The previous NP 304 project was organized by Kevin Hackett and it is one of the largest projects in the Agency. The process used in the last cycle involved different laboratories interacting to address major national needs. Most laboratories had flexibility to bid or compete for specific objectives. The process of developing PDRAMs is fairly consistent and involves negotiations between National Program Leaders and Research Leaders.
- The specific history of this effort with SIMRU was not known, but Deb Fravel suggested that Units should focus on questions of "*what do we want to be?*" and organize their request for research objectives around these broader topics. Luttrell responded that SIMRU had actively worked to define new mission and unit vision statements over the last year. All agreed that now would be a good time for the Unit to start thinking about future research needs. An understanding of the project management process and an ability to effective communicate measurable objectives in the project description would improve the effort.
- Fravel also discussed lessons she had learned from NP303. Scientists tend to be lumpers or splitters. She tended to prefer more broadly stated objectives with specific measurable sub-objectives. The process seems to work best if scientists start developing plans and ideas 1.5 years in advance. Having a few (1-3) major objectives and a clear idea of Unit mission should make writing simpler. Quality of writing is critical, and Fravel suggested that scientists should get peer reviews to help with clear communications. She further suggested that the project should make sense. Scientists should think about how this project looks from the outside. Always remember that our stakeholders lobby Congress for specific needs. The language of our proposed work should address these needs. These same issues are relevant to collective management of publications and overall scientific information. We need to think about how this information looks to the outside world.
- Ryan Jackson added that he reviewed the Formosan Subterranean Termite project and thought that it was a well written concept. Beverly Wiltz responded that it was easy because the previous Unit focused entirely on this insect pest. Roy Scott added that Research Leaders have responsibility to mesh Unit mission with National Program objectives and that there should be a focus on overall unit support and mission. That said, stakeholder interests, Congressional Districts and specific needs of commodity interests are needed to justify projects.
- Roy Scott also described the current NP301 effort and explained the importance of concept papers in developing project goals. Defining "*what we want the project to be*" is a critical first step and engaging the stakeholder in the process is important. He indicated that SIMRU appears to be doing that with the serious of meeting held over the past few months.
- Scott also reminded the group of potential overlap of activities in different National Program and that he was interested in looking at linkages among projects. He is specifically interested in looking at what had been produced (i.e. what are the deliverables, what was the starting effort, what were the products of the investment). He emphasized that project titles are important and that the titles communicate major concepts of commitment to OSQAR and stakeholders.
- Luttrell mentioned possible collaborations with Jeff Willers, of the ARS group at Mississippi State, who works in NP216. Scott and Fravel both indicated that these cross collaborations, and interactions among crop production and natural resources were important and

meaningful interactions. Scott further explained his interest in linking NP301 and NP304 and encouraging networking of plant breeders, entomologists and plant pathologists. Packaging this work into total dollar impact for growers would be a meaningful measure of the value of our research. Interactions with non-traditional crops, for example switch grass, could have production impacts on grain crops. Soil and water, heat and drought stress are all issues that impact production agriculture and national resource interests.

Luttrell asked the National Program Leaders about advice related to future grant funds. Are there specific areas they see that SIMRU should be working toward? Dan Strickman responded that NIFA is probably the key area. He recommended that scientists should be developing relationships with the key contacts in the granting projects and looking for linkages to industry. NIFA is growing and changing, and it is a good time to organize research teams for grant competitions. He also indicated that some of SIMRUs work, specifically the taxonomic and biodiversity work might have possibilities with NIH or NSF. Thinking about the Mississippi Delta and biodiversity could be a possible idea. This would need to include the total ecosystem and native species as well as the cropping systems. The Gates Foundation is very interested in issues that impact developing world issues. He wondered about the possible applicability of *Lygus* and worldwide impacts including Europe and funding opportunities associated with European interests. USAID probably has more applicability for medical/veterinary pests, but there could be possibilities. Possible linkages to EPA and research needs for regulatory issues are a possibility. Luttrell explained some of the current linkages between SIMRU and EPA interests in resistance management. The National Program Leaders reminded the group of the role of ARS research and the differences in policy versus researchable questions, but also encouraged the Unit to participate in research areas as appropriate.

Luttrell asked about National Program interests in sustainability issues. This resulted in additional discussion and clarification of the meaning of "sustainability" within the context of the question. Sustainability is obviously a word used as jargon and with many different contexts. Luttrell explained that he was specifically asking about the impact of insect management practices on ecosystem sustainability values and the concept of valuing products (i.e. Walmart Corporation or other retail interests) grown under different systems of pest management (i.e. organic farming, low pesticide input, etc). The group indicated that linkages to natural resources and ecological issues were important, but that they did not see major influences of these issues on NP 304 planning and current projects. Precision agriculture and reduction of non-target impacts of pest control are important concepts.

Following an expression of appreciation from SIMRU scientist for the time and willingness of Deb, Roy and Dan to visit SIMRU and spend a day taking about research needed, the meeting was adjourned at 3:30 pm. Luttrell gave the National Program Leaders a tour of the 160 acre research farm managed by SIMRU, SIMRU laboratory facilities in Building 1 of the Jamie Whitten Delta States Research Center, and a general tour of the Stoneville facility. A detailed tour of the renovated Building 1 facility was planned by Lawrence Young, Location Coordination, for the following day.

Agenda -- Research Discussions –May 2, 2012
USDA ARS National Program Staff and Southern Insect Management Research Unit
National Biological Control Laboratory Conference Room, Stoneville, Mississippi

9:00 am — **Introductions, Welcome, SIMRU History, and Purpose of Meeting**

9:15 am — **Overview of SIMRU Research Structure and Projects**

- SIMRU Mission/Vision, Delta Agriculture and National Program (Luttrell)
- IPM/IRM Research Project (Jackson)
- Bt Resistance Project (Perera)
- Alternative TPB Management Project (Snodgrass)

Overview of Individual Research

- L. Adams – Sweetpotato/Corn Research
- C. Allen – Soybean/Cotton and Corn Insects
- R. Jackson – Cotton and Corn Insects/Resistance Management
- D. Adams – On-farm Field Studies
- R. Luttrell – Cotton and Corn Insects/*Beauveria*/Bt Resistance
- O. Perera – Bt Resistance/ TPB Genetics
- M. Portilla – TPB and *Beauveria*
- G. Snodgrass – TPB Resistance/*Beauveria*
- Y. Zhu – TPB Resistance/Sugarcane Borer Bt Resistance

10:30 am – 10:45 am — **Break**

10:45 -- Noon — **New Programs and Collaborations With Other Research Groups**

- B. Wiltz – Transition from Formosan Subterranean Termite Unit
- Specific Cooperative Agreements – Alcorn State, Delta Research and Extension Center, Mississippi State University, Cornell University
- Collaborations with Other ARS and University Research Groups

Overview of National Research Programs and Future Research Needs

- Changing National Programs and Project Management Across Locations
- Anticipated Future National Needs
- Unique Mission of Applied ARS Research (Future Values and Needs)

12:00 noon – 12:30 pm — **Lunch with ARS MSA Administration, Delta Council, SIMRU Scientists**

12:30 pm – 3:15 pm — **Continue Discussions of National Programs and Future SIMRU Research**

- Changing Agricultural Landscape – Needed Cross-Commodity Research
- Priorities for ARS – Corn, Cotton, Soybean Insect Management (linkages to other ARS programs, overall crop production, insect science)
- Resistance Management/Regulatory Issues (access to proprietary toxins/proteins; monitoring versus mechanisms, field impacts)
- Short- versus Long-Term Insect Management Research
- Commodity Protection versus Pest Population Management Focus

3:15-3:30 pm — **Break**

3:30-4:00 pm — **Tour of SIMRU Research Facilities/Continued Discussions at NPL Discretion**

Appendix D

SIMRU's 2012 STEP Employees

3rd row (L to R) Thomas Sherman, Julian Beamon, Julian Henry, Dustin Picklemann, Frank Chandler, and John Austin Coleman
2nd row (L to R) Andrea McNeal, Jesse King, Bailey Tubertini, Christopher Morris, Emily Mosow, Russel Godbold, David Liang, and Maria Benavides
1st row (L to R) June Jones, Laura Sipes, Cavishia Roberson, Rebecca Worsham, Jana Slay, Jordan Tullos, and Padmapriya Chatakondi
Not pictured: Flenadia Moore, Dquan Wilson, Sydney Holleman, Darshanisha Warren, Ari Esters, and Taylor Dobbins