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Keynote Address

Future of Entomology – Casting a Wider Net

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Thank you for the honor and opportunity to address the membership of the Mississippi Entomological Association (MEA) and attendees of MEA's 54th Annual Conference. As an Alumnus of the Department of Entomology at Mississippi State University (MSU), this is a special privilege because I have so many good friends and acquaintances here in Starkville and have always cherished my time and experience here. The theme and bottom line of my presentation today is simple – ***the future of entomology has never been brighter for current professionals, practitioners and students.*** To support this premise, I will take two distinct paths based on my two current roles, first as President of the Entomological Society of America (ESA) and second as Global Leader of Crop Protection R&D for Dow AgroSciences.

Role of the Entomological Society of America in Casting the Net

The ESA is actively on the move to meet the needs of its members long into the future. As a professional society, we have a great heritage based in innovation, initiative, and influence (which, incidentally, is the 2007 ESA Annual Meeting Theme in San Diego December 9-12!) within the broad science of entomology and certainly with the genesis and development of Integrated Pest Management (IPM) and economic entomology. But, as with all things, the environment and basic assumptions change over time and it was clearly time for the ESA to revisit the long term value proposition to its members and consider change. The ESA Governing Board did just that beginning in 2000 with an extremely dire financial crisis stimulated from declining membership, unsustainable infrastructure cost, and unrealized revenues from publications and meetings. This crisis was deliberately addressed through a wide range of draconian measures that effectively saved the ESA and has put us in a position where today we have almost $5 Million in reserves and an annual operating surplus such that we actually reduced membership dues to 2004 levels. Managing a crisis is all consuming and there was no time in 2000-2001 to explore the long term questions related to the ESA, but we did begin that journey in earnest in 2002 under the banner of a "Renewal" and I was very pleased to see the membership approve the final Governing Board proposals earlier this year. If you are unfamiliar with this journey, it was documented in detail within an article written by Kevin Steffey and myself published in ***American Entomologist*** (2006 Fall Issue; Volume 52, Number 3).

Breaking it down, this Renewal is about streamlining ESA Governance, focusing volunteers and staff on building excellence with four key capabilities, and empowering four newly configured Science Sections to act on behalf of their membership. Each of these objectives, we believe, will improve the relevance of entomology and lead to new opportunities for entomologists. The current structure of the ESA was designed in 1953 with the merger of the (original) *ESA* and the *American Association of*

Economic Entomologists – two pioneering entomology groups within the United States in need of critical mass to grow and expand influence. As is natural, the result of this merger was more of two associations under one roof versus one designed-from-scratch organization, but there is no denying that the structure has served entomologists well for over 50 years. The burden of managing 14 official governing entities (6 Sections and 8 Subsections), however, takes such a large administrative toll on volunteers that there is little opportunity to advance new capabilities beyond our hallmark Annual Meeting. The Renewal has addressed this by reducing Science Sections to four broad-based groupings that "own" four critical capabilities for ESA membership: (1) public and science policy outreach, (2) fostering interest in entomology, (3) program and issue leadership, and (4) continuing education. These capabilities, if developed effectively by Sections, will lead to a new and necessary level of leadership by entomologists that will create new possibilities, new contacts, and new opportunities for our profession. In order to put the "bite" into Sections and support their capability development, the ESA will also provide them with monetary resources and administrative support – along with far fewer restrictions in general, including the ability to affiliate with sister organizations of similar interest, to develop positions on relevant topics, and to participate in stakeholder meetings on behalf of the Section membership. To provide consistent leadership, the Sections will now elect a Section Governing Council consisting of a President, Vice President, Vice-President Elect, Past President, Treasurer, and ESA Governing Board Representative to oversee the operations, policies, and priorities of the Section.

In addition to the streamlined ESA Governance structure, perhaps the most innovative and elegantly simplistic concept of the Renewal is the notion of Member Networks. The Network concept is to encourage groups of individuals of all special interests within entomology to use the ESA as a venue to explore their commonality – without any obligation to the ESA, no regulation, and no strings. Similarly, the ESA does not provide any entitlements to Networks, but will provide a range of "encouragements" for Networks to use the ESA as its preferred venue, including special self managing software and support with arranging meeting space within the ESA Annual Meeting as possible. Already, over a dozen groups have contacted the ESA to register their network and the list of possible networks is far larger – the Governing Board asked students for areas of common interest in 2005 and they identified over 60 special focus groups! We believe the flexibility of networks will effectively separate the "business" of ESA from the overwhelming interest and need for collaboration among members. In effect, the ESA will become a synergist for innovation and initiative through Member Networks and that power will enable expansion of our science and our membership.

The final way in which the ESA can cast a wider net for entomology is through the creation of an International Branch to supplement the existing North America-based Branches. This suggestion was originally included in the Renewal Proposal, but was delayed to allow the *Standing Committee on International Affairs* the opportunity to study the details and formulate a specific proposal. The benefits would be to better integrate entomological science from all parts of the world to "unite" all types of entomological associations as a means to multiply influence. Benefits could be realized based on scale, value of diversity and inclusion, and professional and personal enrichment.

With all of this focus on renewal of Sections and possibly adding an International Branch, the focus of ESA Central and the ESA Governing Board will be dedicated to continued strategic growth and with ownership of the Communications Capability for the ESA. In fact, just recently a new publications strategy was approved that includes five key strategic elements: (1) shift access and revenue model to favor authors and members (e.g., migrate away from page charges for authors), (2) improve the profile and impact of ESA journals, (3) globalize the reach and focus of ESA journals, (4) anticipate, adapt, accommodate "focus" shifts in entomology, and (5) establish operational goals to improve stakeholder experience. In addition to bringing these important strategic elements to life, ESA Central will continue to focus on the Annual Meeting, the website and all fiscal components of the ESA.

While the renewal concepts and components are by no means perfect, they were proposed with the best interest of the ESA and entomologists in mind. If they are successfully implemented and our volunteers continue to provide exceptional leadership as has been the case since 1953, the ESA will indeed be a key mechanism for casting a wider net. There is strength in numbers and that strength, combined with our ESA tradition of innovation, influence, and initiative makes it very bright for our profession.

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Role of Innovation in Casting the Net

As noted previously, the science and profession of entomology has been the leader among other disciplines in the rational approach to pest management and crop protection. Since the genesis of IPM by Stern et al. in 1959, entomology has been in the leadership position conceptually, but Stone and Pedigo (1972) integrated practical concepts of bioeconomics with the introduction of the Gain Threshold. This simple yet elegant concept puts into perspective the dynamics of control costs and market value, which can then be related to injury and damage relationships to calculate a workable Economic-injury Level (EIL). Indeed, it is the dynamics of the EIL that makes Integrated Pest Management (IPM) such a powerful concept because there is no single answer to covers all pest scenarios and a plethora of questions must be assessed with site-specific data and circumstances. A grower's perspective on income risk, personal values, and the range of technology options are just a few considerations that must link with the bioeconomics of the scenario. IPM, then, is simply the application of all available knowledge/insights for good business.

More and more, the technology focus for pest control within IPM is driven by three highly valued grower criteria – reducing complexity, increasing convenience, and minimizing cost. These three criteria, while not as objective or elegant as the bioeconomics of gain thresholds and EILs, is driving a great deal of technology discovery and development today – and therefore is relevant to the notion of casting a broader net for entomologists. In short, technology focus has shifted significantly toward preventive tactics. This is due in large part to three things – (a) raising commodity and crop prices, (b) reduced cost of many technologies, and (c) the availability of new preventive technologies (e.g., transgenic insecticides, seed treatments). Of course, there also is a great deal of innovation space still available for curative technology.

Curative products for crop protection have many success stories for improving their footprint, their regulatory profile, their convenience, their cost, and their utility in IPM. The challenge is to describe a vision for what a product should do differently and then to explore and match technologies to address those attributes. Too frequently, product attributes for an active ingredient are believed to be incremental and the notion of a "breakthrough" is not considered seriously. Often our lack of imagination is our biggest limitation! At Dow AgroSciences, we have renamed our formulations function to "Product Design" in recognition of the significant impact and value that can be achieved with rational design of formulations AND delivery systems. In this journey, we carefully design products to meet emerging and future regulations for the active ingredient and for the co-formulants selected to make the product. In addition, there are numerous ways to improve the biological performance, user attributes, or cost of products – and these opportunities have just begun to be fully explored and exploited.

There are numerous examples of where formulation method or delivery system can significantly reduce the toxicological or environmental profile for products and in some cases this has actually enabled registrations in countries not previously available for consideration. Moreover, tremendous opportunities continue to exist for reducing volatility and drift resulting in potential non-target effects from spray applications through in-can formulation technologies. On more of a breakthrough scale, photo stability improvements are greatly improving the performance profile of existing actives through new and novel use of co-formulants and methods. In areas specifically relevant to entomology, baits and baiting systems have demonstrated stunning effectiveness for termite colony elimination and control of quarantine pests such as Mediterranean fruit fly. Seed treatments are of course common, but the science behind coatings in a broader sense is just now emerging and holds great promise, as does the potential for nanomaterials. These are extremely exciting times for agriculture and insect pest management, with most companies having rich and diverse pipelines of chemical and biological solutions in both discovery and development stages – in this context, the promise of IPM is indeed delivering. If the economics of agriculture are strong, then the science and the profession of entomology will parallel this strength and serve to further cast the net for entomologists in the public- and the private-sectors.

In summary, the future of entomology has never been brighter. The science has never been so diverse, the application of the science to agriculture has never been so important, and the opportunity for entomologists to lead through their professional Society has never been greater. My challenge to entomologists at all stages of your career is to make a difference – the possibilities are limitless and we have a great foundation and heritage in IPM and the ESA to build upon for our widening net(work)!

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Activities and careers within APHIS/ PPQ. Jeffery L. Head. State Plant Health Director, USDA, APHIS, PPQ.

[Abstract not on file]

Entomological consulting – now and in the future. Bruce Pitman. President, MACA.

[Abstract not on file]

Safeguarding Mississippi from invasive insects. Benny L. Graves. Division Director, Plant Pest Programs, Bureau of Plant Industry.

[Abstract not on file]

Insect rearing educational opportunities at MSU. Frank M. Davis. Emeritus Adjunct Professor, EPP, MSU.

[Abstract not on file]

Student Paper Competition

Evolution of host plant preferences and analysis of biogeography based on a phylogeny of holarctic Teleiodini (Lepidoptera: Gelechiidae). S. Lee and R. L. Brown. EPP, MSU.

Evolution of host plant preferences and analysis of biogeography based on a phylogeny of holarctic Teleiodini (Lepidoptera: Gelechiidae). Synopsis: Phylogenetic relationships of 25 genera of holarctic Teleiodini (Gelechiidae) are postulated based on morphology and molecular characters, including CO-I, CO-II and 28S genes. The phylogenetic analysis of the combined morphology matrix and the CO-I + CO-II + 28S Mtrix yielded two equally most parsimonious trees (length 1184 steps, CI = 0.50, RI = 0.41) and a strict consensus tree (length 1187 steps, CI – 0.50, RI=0.40). An analysis of larval host plant preferences based on this consensus tree indicates derivation of feeding on woody hosts from genera feeding on herbaceous hosts and a single origin of feeding on coniferous hosts. An area cladogram indicates five independent origins of Nearctic genera from Holarctic ancestors and one origin from a Palearctic genus.

Effective population sizes and spatial variation of genetic structure in the invasive species *solenopsis invicta* buren, the red imported fire ant. Rajesh Garlapati, Michael A.Caprio, David Cross, O. P. Perara. MSU. Dept. EPP.

The fundamental goal of population genetics is to understand the relative importance of micro evolutionary forces in determining the existence of genetic variation within a species. The variance in effective population size is an important quantity in evolutionary biology, which helps in describing the rate at genetic variance changes due to genetic drift. The fire ant represents an excellent model system to conduct detailed studies of genetic structure using many markers of multiple classes. With this rationale a study was initiated to assess genetic differences of fire ants among different places and to estimate effective population sizes in the presence of gene flow.

Farmland butterflies benefit from CP33 native grass buffers. J. A. Goldenetz, T. B. Watkins, H. L. Puckett, S. K. Riffell and L. W. Burger, Jr. WF, MSU.

[Abstract not on file]

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Species level problems of *Donacaula* (Lepidoptera: Crambidae) of the Western Hemisphere. Edda Martínez and Richard L. Brown. MSU, Entomological Museum.

Little information is available concerning the distribution and biology of *Donacaula* species in the Western Hemisphere, in part because the difficulty of their identification. All species of *Donacaula* are very similar externally, with the forewings light to dark brown and some species with longitudinal dark lines or spots, but variation in these patterns have added confusion in their identification. The similarity within the genitalia also created confusion for their identification. The use of whole body mounts should provided new characters at both generic and specific level for their identification. Preliminary results of the phylogeny of the Schoenobiinae using traditional characters of genitalia and wing venation and new characters of the whole body are presented.

Programming Techniques to Search and Process Acoustical Data from Insects. Vijay Ramalingam*, Tom Fink*, John Seiner*, Douglas Streett** and Alan Lax** *National Center for Physical Acoustics, University of Mississippi, University, MS, 38677 ** *ARS, USDA, Stoneville, MS.*

A LabVIEW® based search program is written to search through the meta-data information embedded in insect sound and vibration data stored as WAV (Windows Audio Format) recordings. The meta-data information such as weather data and experimental setup data is embedded into the WAV files during data acquisition, and this enables the search for specific files from our acquired data using our search program. An Microsoft Excel® Macro is written to process the FFT (Fast Fourier Transform) data created by LDS-Dactron: RT Pro Photron® system. The macro imports the FFT text file, formats and plots the FFT data, and finally exports the graphs to Microsoft PowerPoint®. Substantial time savings were achieved during data analysis by implementing these procedures.

Molecular markers and their utilization in migratory studies of Helicoverpa zea in North Mississippi. S. R Vemula,., M. A. Caprio, J. C. Schneider and F. R. Musser. Dept. of EPP, MSU.

Population genetic structure of field collected adult moths of Helicoverpa zea was investigated using novel markers to comprehend the temporal and spatial variation in genetic structure. Emphasis was laid on understanding the migratory behavior of adults moths collected over the season (2005-2007) from Northern Mississippi. Genetic markers used in this study included Inter-simple sequence repeats (ISSR), Simple sequence repeats (SSR), and Sequence-related amplified polymorphism (SRAP). Polymorphism at different loci was utilized in estimating the temporal and spatial differentiation of the adult populations. A comparitive study was done using these markers to identify the best marker for population genetic studies in Helicoverpa zea . This knowledge will be used in further population genetic studies of this pest.

Ornamental plants as nectar source for *Larra bicolor*. C. M. Abraham and D. W. Held. Dept of EPP, MSU.

A Comparative Analysis of Fluorescence from Different Stains for Imaging with a Confocal Laser Scanning Microscopy. R. Brown, S. Lee and W. Monroe. EPP MSU. Synopsis: _ Confocal laser scanning microscopy can provide high resolution and three-dimensional images by stacking consecutive scans of confocal planes. Confocal microscopy is dependent upon degree of florescence caused by different colors of laser light. Confocal microscopy rarely has been used for examining and imaging anatomical structures of Lepidoptera and other insects, and examples of its use for imaging slide mounted structures of Gelechioidea are provided. A comparison is made of the florescence and quality of images of genitalia that are stained with eosin, mercurochrome, chlorazol black, chlorazol black + eosin, saffarin and orange-G – all of which are currently used by various lepidopterists. Stains that provide optimal fluorescence are recommended.

The role of Gulf Coast ticks (*Amblyomma maculatum*) in the epidemiology of *Rickettsia parker*i infection. K. T. Edwards and J. Goddard. Dept of EPP, MSU.

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The Gulf Coast tick, Acari: Ixodidae, *Amblyomma maculatum* (Koch), is a Nearctic and Neotropical three-host tick. The larvae and nymphs of this species are common pests of ground-inhabiting birds and small rodents. Adults have no particular host specificity, attacking a variety of vertebrates including humans. *Amblyomma maculatum* is widely distributed in Oklahoma, Kansas, and the Gulf coast, generally up to 150 miles from the coastline, along the Mississippi River and in the Atlantic states. It is also found in several Central and South American countries bordering the Gulf of Mexico and Caribbean Sea. Rickettsial organisms, such as the ones causing Rocky Mountain spotted fever, are often associated with ticks and may belong to the spotted fever group (SFG), typhus group (TG), or scrub typhus group (STG). Rickettsiae multiply in almost all organs of invertebrate hosts; ticks become infected with the bacteria by feeding on bacteremic animals; then infection may occur transstadially and/or transovarially. In 1937, Ralph Robinson Parker (1888-1949) isolated a rickettsia-like organism which differed significantly from *Rickettsia rickettsii*, the etiologic agent of RMSF. He isolated this organism from *A. maculatum* ticks collected from cattle in Texas when all confirmed cases of tick-borne spotted fever were attributed to *R. rickettsii*. In 1965 the agent identified by Parker was confirmed as a unique SFG rickettsia, *Rickettsia parkeri*. Little is known about the natural history of *R. parkeri*, that is, reservoir hosts (birds or mammals) and the tick/vector components. The medical importance of the Gulf Coast tick was highlighted in 2004 when Paddock et al. described the first recognized case of infection in a patient with *R. parkeri.* From the first reported case of infection with *R. parkeri* in *A. maculatum* ticks in cattle in Texas by R. R. Parker, it has been known that cattle played a role in the epidemiology of *R. parkeri* infection. Early studies focused on the implications as a predisposing factor for screwworm infestation. More recent studies have documented decreased weight gain and alterations in blood composition after infection with *R. parkeri.* Adult *A. maculatum* ticks have a predilection for cattle ears; nymphs demonstrate a preference for the withers, midline, and tail-head. Ears may become thickened and curled, causing a condition called "gotch ear". In addition to the nuisance effect of ticks and blood loss from heavy *A. maculatum* infestations, cattle may have up to a 20% growth performance reduction. However, little is known about the pathogenesis or epidemiology of gotch ear in cattle except that it involves *A. maculatum* ticks. The objective of this study is to elucidate the natural history of *R. parkeri* infection in *A. maculatum* ticks, and specifically, in relation to cattle.

Amblyomma maculatum female

Amblyomma maculatum male

Gotch ear in cattle ear.

Stalk strength as it relates to insect penetrability. B. Gibson and F. Musser. EPP, MSU.

[Abstract not on file]

Spider mite response to seed treatments and cotton yield loss associated with late-season damage. J. Smith, F. Musser and A. Catchot. EPP, MSU.

[Abstract not on file]

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Stridulation behavior of *Solenopsis invicta* and *S. richteri* at different food sources. J. R. Marquess and J. B. Anderson. UMFS/CWWR, UM.

[Abstract not on file]

Chrysomelid beetle (Coleoptera: Chrysomelidae) associations with sweet potato in Mississippi. D. Fleming and J. T. Reed. EPP, MSU.

[Abstract not on file]

*** A comparative analysis of fluorescence from different stains for imaging with a confocal laser scanning microscope.** Richard L. Brown, Sangmi Lee**,** and William Monroe. MSU Entomological Museum.

[Abstract not on file]

* Not in student competition.

Concurrent Paper Session

Termite consumption of charred wood. C. J. Peterson, P. D. Gerard and T. L. Wagner. USDA-Forest Service, Starkville, MS.

Termites play an important role in the decomposition of wood in forest ecosystems. Charring alters wood by converting cellulose to other products, eventually mineralizing cellulose to carbon dioxide, water vapor and ash. This study examined the effects of char on termite gut protozoa and the termites' ability to find and begin feeding on charred wood. Termites that were force-fed char showed a reduction in the number of gut protozoa, but not to the degree seen in starved termites, indicating that termites derive some nutritional value from char. Tests of charred boards in the laboratory and charred bolts in the field revealed that the presence of surface char did not affect the termites' ability to find the wood and begin feeding. We conclude that because termites very likely survive low-intensity fires, there will be no interruption of termite contributions to the carbon and nutrient cycles of forests.

South Louisiana ants two years after hurricanes Katrina and Rita. B. A. Wiltz. USDA-ARS, SRRC, New Orleans, LA.

Ant populations in South Louisiana have been monitored since hurricanes Katrina and Rita. Changes in species distribution from before the hurricanes through the present will be discussed.

Eavesdropping on Colonies of the Black Imported Fire Ant, *Solenopsis richteri.* Timothy O. Menzel, Jake R. Marquess, Tom Fink, John Seiner and Douglas Streett.* National Center for Physical Acoustics, University of Mississippi *USDA-ARS-BCMMUR, Stoneville, MS

Our objectives were to 1) record acoustic signals from colonies of the black imported fire ant, *Solenopsis richteri* Forel, 2) identify significant patterns within those signals, 3) quantify the occurrence of those patterns across all recordings, and 4) study the relationship between those patterns and other measured variables. A 50 cm long spike was driven into the center of seven ant colonies, leaving 2 cm of the spike above the mound surface. An accelerometer (1 volt/g PCB 352B) was then attached by magnet to the top of the spike to receive and measure substrate vibrations from within the colony. Signals were then passed through a signal conditioner (PCB Model 480M167) into a laptop computer and recorded using Raven (1.3) software. Recordings were made once a week for five weeks in May and June of 2007 between the

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hours of 9 and 10 am, 12 and 1 pm and 4 and 5 pm. Sixty-two viable 5 minute recordings were obtained from six of the seven colonies.

Three distinct patterns were identified from the wave forms; single spikes (“pops”), collections of spikes which sounded like a grinding noise (“grinds”), and stridulation, a well document acoustic behavior involving the scraping of structures on the petiole and gaster (Figure 1). Pops were detected in 100% of recordings of occupied mounds at a rate of about one per second and were determined to be a useful way of distinguishing active from abandoned nests. Grinds were found in 95 % of active colonies and there was great variation in the number of grinds per unit of time. Stridulation was detected in 14% of recordings and was in most cases a single isolated event.

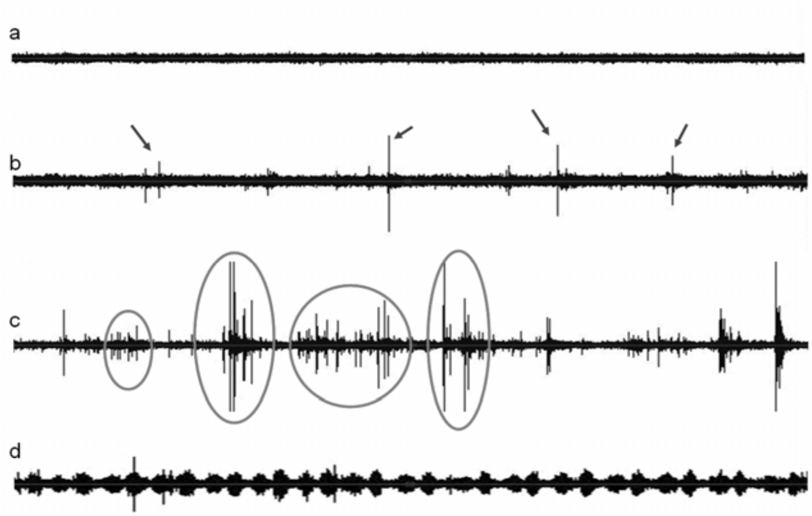

Figure 1. Five seconds of wave forms from four separate recordings: a) from an abandoned mound, b) from a colony with minimal activity, arrows indicate spikes referred to as “pops” in the text, c) from a very active colony, circled areas indicate collections of spikes referred to as “grinds” in the text, d) a stridulation pattern.

To determine the behaviors that can be associated with the different patterns described, an experimental chamber was used that was similar to an ant farm but with a grid of metal screws embedded to act as wave guides for acoustic signals. As ants tunneled through the chamber their signals could be picked up by an accelerometer attached to the closest screw. Using this method we were able to observe the behavior associated with grinding but not with the other two patterns. The grinding noise was generated by ants while excavating and was generated by the sound of soil scraping against soil. Grinding was quantified for each recording by dividing recordings into 60 five second intervals. The presence/absence of grinding was noted for each interval and then used to determine the percent cover of grinding for each recording.

The 62 recordings were then divided into groups by time of day, presence/absence of visible worker activity during recording, presence/absence of stridulation, and colony, to determine which division(s) accounted for the variation in grinding (excavation) behavior. The only division where variation between groups was noticeable was between colonies, and there was comparably little variation within colonies (Figure 2). There are two logical explanations for this relationship; 1) the variation is related to the placement of the spike, which could be better situated for receiving signals from excavation in some colonies than others, or 2) some colonies are excavating more than others. To test the first scenario, a future experiment will be conducted where several spikes are implanted into single colonies and recordings are taken simultaneously from all spikes. If there is no or little variation in the patterns detected from the different spikes, that would reduce the possibility that the variation in excavation detected was due to spike placement. In this case, another experiment could be conducted where recordings are taken from several colonies, the level of excavation is determined for each colony, and then colonies are exhumed to determine the relationship between various life stage characteristics, such as brood stage and colony size, and excavation behavior.

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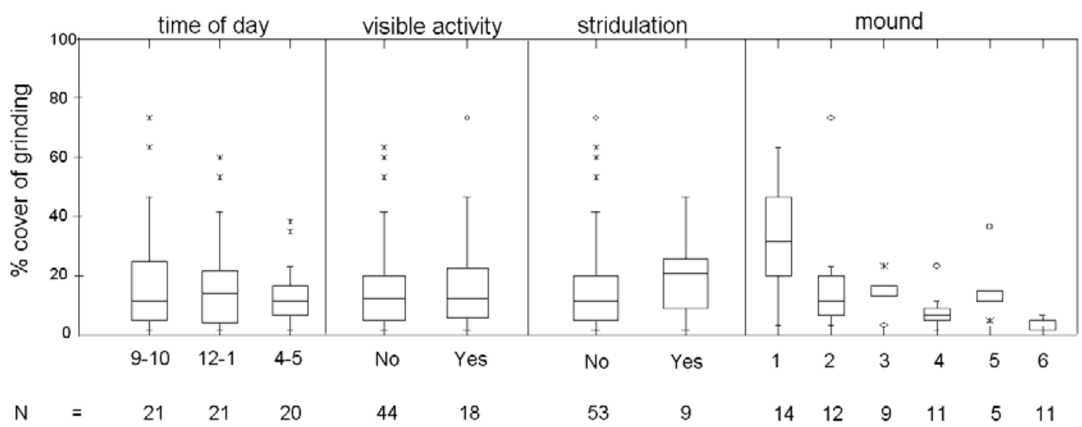

Figure 2. Percent cover of an excavation related pattern from 62 recordings, separated by time of day, presence/absence of visible activity, presence/absence of stridulation and mound recorded.

Phase-averaged Investigation on Fire Ant Wingbeat Induced Flows with digital PIV. L Gui, T Fink, Z. Cao, D. Sun and J. M. Seiner. National Center for Physical Acoustics, University of Mississippi.

A particle image velocimetry (PIV) system was developed and applied to investigate the air flows induced by the motion of fire ant alate wings. The experimental setup is shown in Fig. 1. A special fluid is injected into the heater of the fog generator by a syringe pump with a flow rate of 0.1 ml per minute to create fog particles of a few micro-meters in diameter. The fog is clean and not harmful for humans and the tested insects. Fresh air is mixed with the fog particles and driven by heat convection into the test chamber of $100\times100\times150$ mm^3 through a 75 mm aluminum pipe with a low flow speed that can be ignored in comparison to the fire ant wing beat induced flow velocity. The tested flying fire ant alate is tethered on a fine metal wire (0.3mm) and held at the test position in the fog chamber by a 3-D traverse system. A pulsed beam from a Nd:YAG laser is converted to a thin ($\approx$0.5 mm) light sheet in the test region through a set of light sheet optics that includes a cylindrical divergent lens, a mirror and a cylindrical condenser lens. The laser is controlled by a delay & pulse generator so that double laser pulses of 100 μs time interval are sent out at repeating rate of up to 30 Hz to illuminate the fog particles in the light sheet. A PCO 2000 camera is synchronized to the laser pulses with the delay & pulse generator to acquire particle image recording pairs. The acquired particle image recording pairs are evaluated with a correlation-based central difference image correction method (CDIC) to determine instantaneous velocity vector maps. Statistical analysis is applied to groups of instantaneous velocity vector maps to quantify the mean velocity distributions and velocity fluctuations, i.e. the normal and shear Reynolds stresses of the turbulent flows. To investigate the velocity, vorticality and turbulent value variations in a wingbeat period, a phase averaged analysis was conducted as follows: (1) Acquire more than 10,000 PIV recording pairs that include the fire ant images in the background; (2) Process images with high-pass filters and evaluate image pairs to determine flow velocity vector maps; (3) Process images with low-pass filters to enhance wing images for determining phase of each vector map; (5) Divide the vector maps into around 20 groups according to the phases; (4) Conduct statistical analysis for each phase group, i.e. of around 500 velocity vector maps. Tests results will be presented and discussed in the MEA annual meeting, October 25-26, 2007.

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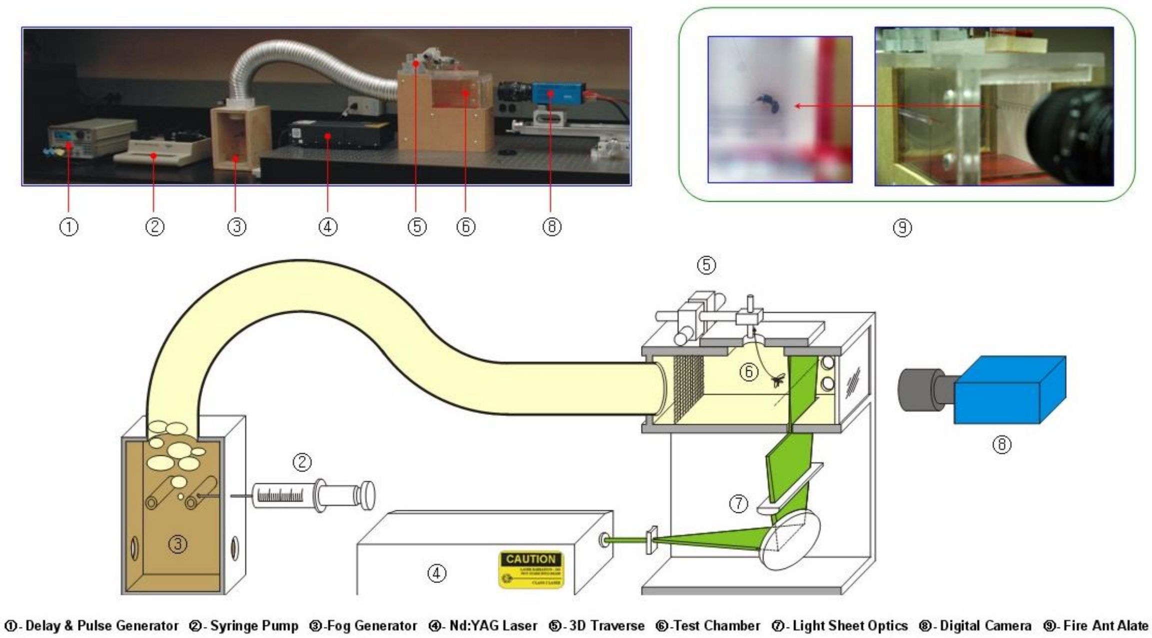

Figure 1: Experimental setup for measuring air flows induced by the fire ant wingbeat

Cultural aspects of sweet potato insect management in Mississippi. J. T. Reed, C. Jackson, D. Fleming. EPP, MSU.

Cultural practices in sweet potato production in Mississippi includes a soil-incorporated pre-plant application of insecticide (PPI) prior to the planting of slips. Planting may be done from May to mid-July with harvest following from 80 to 100+ days after planting. There may be a lag of few days to 2 months between the PPI application and planting. Sweet potatoes may be planted in fields following other crops and are generally rotated following 2 or three years of sweet potato in the same field. Research has been concluded that relates to these cultural practices, and results suggest possible ways of avoiding some insect damaged potatoes.

The lag between the application of PPI and the date of planting resulted in damage to approximately 3% by cucumber beetles and 2.5% by *Systena* flea beetles for every 10 days of lag between insecticide application and planting (cumulative: 18% and 15%, respectively at 60 days). The lag between PPI and planting for other insects was minimal. The data suggest that considerable savings may be obtained by applying the PPI immediately prior to planting.

Additionally, the distribution of insect species throughout the growing season differed with species. Click beetles peaked early in the season (prior to week 29) and few were collected after June. Sweet potato flea beetles and cucumber beetles (*Diabrotica* species) numbers peaked after week 30, and *Systena* flea beetles were present at low levels all season with no major peaks in population. These data suggest that foliar applications of insecticide may best be utilized by making one or two applications for adult click beetle management early in the season beginning immediately after planting, and by applying insecticide from mid- to late season to within a few weeks of harvest for cucumber and flea beetle management.

The percentage of damaged potatoes tended to be higher in sweet potatoes following a fallow field (pasture) or soybeans, indicating that it would be best to rotate planting of sweet potatoes to follow cotton, corn or sweet potatoes, and to avoid planting in fields that were fallow the previous year.

Sampling procedures include sweep-net, vacuum, and sticky cards. Although there are some benefits to each system, sweep net samples are recommended for chrysomelid pest species.

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Applications of Poisson regression models in site-specific cotton pest control. J. L. Willers. USDA-ARS, Mississippi State, MS. Synopsis: Site-specific samples stratified by classified remote sensing imagery are analyzed by Poisson regression methods.

[Abstract not on file]

Insects of early planted group IV soybeans. G. L. Andrews, J. Robbins and D. Poston. DREC.

Farmland butterflies benefit from CP33 native grass buffers. **J. A. Goldenetz**, T. B. Watkins, H. L. Puckett, S. K. Riffell and L. W. Burger, Jr. Dept. of W& F, MSU. Abstract: Butterflies are critical components of sustainable agricultural systems because they provide valuable services such as pollination, food for wildlife, wildlife-viewing opportunity, and ecosystem health indication. Therefore, agricultural producers are encouraged to promote and protect butterfly populations on their land. One method for increasing butterfly habitat on farmland is the establishment of Conservation Reserve Program (CRP) practice CP33 buffers. In this presentation, I will report how butterfly species have responded to the establishment of CP33 buffers prior to managed disturbance. During the third year after establishment (June-August 2007), we detected 38 butterfly species using CP33 buffers. This community included 11 habitat-sensitive species, comprising 16% of total observations. The presence of these habitat-sensitive species (e.g., Swarthy Skipper, Sachem) is important due to their association with native grass species historically common in the Black Belt Prairie physiographic region of northeast Mississippi. This baseline data will be used to determine the impact of vegetation management (i.e., burning and disking) on farmland butterfly populations.

Role of diapause in the utilization of fall and winter hosts by the tarnished plant bug in the Mid-South. G. L. Snodgrass. USDA-ARS, Stoneville, MS.

Tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois), overwinter as diapausing adults throughout North America. Because of the importance of diapause in the development of control methods for plant bugs, diapause in the tarnished plant bug was studied from 1999-2007 in field and laboratory tests at the Southern Insect Management Research Unit, USDA-ARS, Stoneville, MS. Stoneville is at a latitude of 33.43 N and is in Washington County near the western edge of MS in the Mississippi River Delta. Tarnished plant bugs are native to North America, and in the mid-South they have evolved a diapause that enables them to survive periods when food is unavailable, and take advantage of favorable conditions for reproduction in the fall and winter when they occur. Tarnished plant bugs begin entering diapause in late August and by 12 September about 50% of the developing nymphs will produce diapausing adults. Most nymphs developing in the field in October and November become diapausing adults. However, reproduction in the fall continues in the field on weed hosts until the hosts are killed by a freeze. Reproduction can also occur during the winter with new generation adults produced in March in mild winters. The key to tarnished plant bugs being able to utilize favorable periods of weather for reproduction in the fall and winter in the mid-South lies in two factors. One is the presence of winter hosts (mainly henbit, *Lamium amplexicaule* L.) that bloom in late November through March. The other is the ability of diapausing adult tarnished plant bugs to break diapause in response to temperature and food stimuli. Both of these two stimuli are important, and food must contain nutrients as are found in blooms or flower buds. The laboratory and field tests that determined the importance of food and temperature in emergence of plant bugs from diapause and how this makes plant bugs so well adapted to their environment in the mid-South will be presented and discussed.

Bean leaf beetle resistance to pyrethroids in soybeans. F. Musser and A. Catchot. EPP, MSU.

[Abstract not on file]

Pest Control Updates. A. Catchot, S. Stewart, G. Lorenz and R. Bagwell.

[Abstract not on file]

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Urban Entomology Session

[No abstracts are on file for papers presented in this session]

Putting the urban into USDA, ARS veterinary, medical, and urban entomology national program. D. Strickman. USDA, ARS National Program Leader.

Bridging the gap between basic and applied research: lessons from urban entomology. A. Appel. Auburn University.

Termite research and termiticide registration issues. T. Wagner. USDA, FS.

Area-wide management of the Formosan subterranean termite in New Orleans' French Quarter. B. Wiltz, F. Guillot, and A. Lax. USDA, ARS, New Orleans, LA.

Mississippi's extension urban entomology program. B. Layton. EPP, MSU.

Ornamental and turf grass entomology research in Mississippi: science and serendipity. D. Held. CREC, MSU.

Artificial nest sites for native bees. B. Sampson. Visiting Research Professor, MSU.

New mosquito biolarvicide formulation with enhanced residual activity. M. Lyn and D. Streett. USDA, ARS, NBCL.

Perspectives on imported fire ants and other urban pests in the popular press. J. T. Vogt. USDA, ARS NBCL.

Posters

Seasonal Changes in Broadband Spectral Reflectance Characteristics of Imported Fire Ant (Hymenoptera: Formicidae) Mound Features in Turfgrass Agroecosystems. S. L. DeFauw[1], J. T. Vogt[1], and D. L. Boykin[2] [1]USDA, Agricultural Research Service, Mid South Area, National Biological Control Laboratory, Biological Control of Pests Research Unit, P.O. Box 67, 59 Lee Road, Stoneville, MS 38776, USA [2]USDA, Agricultural Research Service, Mid South Area, P.O. Box 225, 141 Experiment Station Road, Stoneville, MS 38776, USA

Invasive mound-building imported fire ants (*Solenopsis* spp.) disrupt soil quality and turfgrass nutrient management in sod production, recreational, and residential settings. Ground-based implementation of hyperspectral techniques in the detection and seasonal monitoring of imported fire ant colony distributions is a prerequisite for either designing vehicle-mounted sensor arrays or for equipping airborne multispectral digital cameras with appropriate band-pass filters to maximize mound detection for field- to landscape-scale surveys. The objective of this study was to assess broadband spectral reflectance patterns for a widely-used turfgrass cultivar, Tifway 419 (*Cynodon dactylon* x *C. transvaalensis*), grown on various soils (inceptisols, entisols, alfisols, and vertisols), and identify bandwidths that enhanced the detection of imported fire ant mound features. Reflectance data (N=36,180 full-range spectra) were

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collected from mid August through early November 2006 from two field sites with hybrid bermudagrass (cultivar Tifway 419) in the North Central Hills and Delta physiographic regions of Mississippi. Peak summer season results for sparsely covered ant mounds (≤50% vegetation) indicated that mean reflectance values for four target types (i.e., mound soil, undisturbed bare soil, ant-affected turfgrass at mound perimeter, and unaffected turfgrass approximately 2 m away), averaged over 50 nm bandwidths, were most distinctive ($P<0.001$) from each other at 650-700 nm, 1450-1500 nm, and 2000-2050 nm. Reflectance data collected during the Summer-Fall transition (coinciding with peak imported fire ant biomass) displayed shifts in mound feature recognition in the visible (VIS) and near-infrared (NIR) regions, with distinctive bandwidths constrained to just the VIS region ranging from 600-700 nm ($P<0.001$). Fall datasets (acquired late October to early November 2006) displayed the most robust differences ($P<0.001$) in the 2000-2100 nm range followed by 650-700 nm, 600-650 nm, 1050-1100 nm, 900-950 nm, and 850-900 nm. These results suggest that mobile, mower-mounted spectral devices designed to map turfgrass and soil responses to imported fire ant infestations would benefit by providing three to five, user-selected broadbands to optimize mound feature detection across seasons. Development of new remote sensing monitoring tools, employing seasonally-acquired hyperspectral data in turf as a model system, will aid in the implementation of site-specific management of imported fire ant infestations in perennial, warm-season turfgrass settings, help foster sustainable reduction of fire ant populations, and benefit a broad array of stakeholders.

Feasibility studies in fire ant management in minimum tillage soybeans. J. T. Reed, A. Catchot, A. Williams, A. Nagel, D. Bao. EPP, MSU.

[Abstract not on file]

Brachymyrmex patagonicus **(Hymenoptera: Formicidae), an emerging pest species in the southeastern United States.** J. A. MacGown and J.G. Hill. EPP, MSU.

[Abstract not on file]

Management Zone Delineation and Image Resolution Issues in the Site-Specific Control of Tarnished Plant Bugs in Cotton. Patrick J. English[1], Sherri L. DeFauw[2], James W. Smith[1], and Jeffrey L. Willers[3] [1]Mississippi State University, Delta Research & Extension Center, Stoneville, MS 38776 [2]USDA, ARS, Biological Control of Pests Research Unit, Stoneville, MS 38776 [3]USDA, ARS, Genetics and Precision Agriculture Research Unit, Starkville, MS 39762

Precision-based agricultural application of insecticide relies on a non-random distribution of pests. Tarnished plant bugs (*Lygus lineolaris*) are known to prefer vigorously growing patches of cotton, therefore, management zones may be readily defined using NDVI (Normalized Difference Vegetation Index). Field-scale NDVI variability is the combined result of crop response to intrinsic field properties (i.e., soils, drainage, and planting preparations, etc.) as well as weather-related conditions. The objective of this study was to evaluate the interactions of field-scale heterogeneity and the spatial resolution of aerial imagery and their effects on delineating transitions in management zone boundaries for the site-specific control of *L. lineolaris* in cotton. We found that the aerial extents of non-autocorrelated patches increased as image resolution decreased. At 1 m resolution, field-scale percentages of non-autocorrelated areas ranged from 19.4-24.5% (with a mean of 20.7%). However, at 2 m resolution, the range of non-autocorrelated areas expanded to 32.3-43.6% (with a mean of 37.6%). The non-autocorrelated patches represented as narrow linear features denote sharp transitions between potential management zones, whereas irregularly-shaped, omni-directional patches define highly-variable transitions between zones. These latter patches pose problems because they contain highly heterogeneous habitat quality that may not be properly identified in a site-specific application (and in all likelihood not sprayed), thereby serving as refugia and loci for reinfestation of the field by TPBs. The optimal resolution for identifying these heterogeneous zones appears to be related to row spacing and the cotton variety's ability to close the canopy. However, this hypothesis will need to be tested using higher

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resolution imagery, and software capable of processing large acre fields (greater than 100 acres) at resolutions greater than 1 meter.

Molecular cloning of the gene for the allatostatin family of neuropeptides from the hybrid red-imported fire ants (*Solenopsis invicta*). S. Mohan, S. Baird, G. T. Baker, and P. W. K. Ma. EPP, MSU.

[Abstract not on file]

How Crazy Ants move: High-speed and conventional videographic analysis of locomotion in *Paratrechina longicornis* (Latreille). T. Fink. B. Wiltz, L. Gui and D. Sun. NCPA, UM.

[Abstract not on file]

The ant fauna of Black Belt Prairies in Mississippi and Alabama. J. G. Hill and R. L. Brown. EPP, MSU.

[Abstract not on file]

Fungi associated with red imported fire ants *Solenopsis invicta* Buren and mounds in Mississippi.
Sandra W. Woolfolk and Richard E. Baird, Mississippi State University, Department of Entomology & Plant Pathology, Mail Stop 9655, Mississippi State MS 39762 Sww3@entomology.msstate.edu

A study is being conducted in Mississippi to determine fungi associated with red imported fire ants (RIFA) and their mounds. Active mounds containing RIFA, mound soils and plant debris were collected from Hinds, Madison, and Leake Counties along Natchez Trace Parkway Mississippi in March, July, and November 2004. The three counties were selected because they have been confirmed to be occupied by RIFA. Five mounds were collected per time per sampling location. Once transported to the laboratory, samples were processed and isolated onto Sabouraud's dextrose agar plus yeast (SDAY) amended with streptomycin sulfate and chlortetracycline. A total of 1445 different fungal isolates were obtained. Isolated fungi were initially grouped based on morphological features. Two representative isolates from each group were selected and molecular identification is currently being performed using molecular techniques. The initial molecular procedures (DNA extraction, polymerase chain reactions, and DNA purification) have been completed for all isolates, and the DNA sequencing procedure is in progress to obtain all fungal sequence data (~50% complete). As expected, from three sampling locations, most fungi were isolated from plant debris, followed by soil mounds, and ants (externally and internally) (Table 1). Majority of those were saprophytic fungi which are commonly found in soil and/or residents of the phyllosphere. Very few fungi isolated from internal body region of RIFA indicating that they may be transients within the internal body regions of RIFA. *Metarhizium anisopliae* and *Paecilomyces lilacinus*, two species known as entomopathogenic fungi in other insects, were recovered from the three locations. These two fungi along with others that showed potential during laboratory evaluation (data not presented) are being evaluated under field-caged condition to identify their biological control potential.

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Table 1. Total numbers of fungal isolates associated with red imported fire ant (RIFA) soil mounds, plant debris, and external and internal body regions of RIFA from Hinds, Leake and Madison Counties along Natchez Trace Parkway, Mississippi*

Closest GenBank match fungal taxa	**GenBank Accession no.**	**Closest GenBank GI no. (blastn)**	**Hinds County**				**Leake County**			
			SM**	**PD**	**AE**	**AI**	**SM**	**PD**	**AE**	**AI**
Aspergillus flavipes strain UWFP 1022	AY214443	97%					7			1
Aspergillus niger	AJ280006	97%						2		
Aspergillus niger isolate ANL	EF105366	>99%	1	1				3		
Aspergillus nomius	DQ323036	99%	4					1		7
Aspergillus oryzae strain D9	EF488390	98%								3
Aspergillus sp. Ar-4jing-1	EF614252	99%					1			
Aspergillus tereus isolate 720/2K	EF446283	87%					2			
Aspergillus terreus	AY247954	99%					2			
Aspergillus terreus isolate NHRC-F-05-2-1	AJ413985	95%				1	1			
Aspergillus tubingensis strain 3.4342	EF621571	94%		1			6	3		
Aspergillus versicolor	AJ937755	99%								
Ceratocystis adiposa	AM696209	89%						5		
Eupenicillium anatolicum strain NRRL 5820	AF033425	99%					3			
Fusarium culmorum isolate K1006	AY147336	>99%								
Fusarium equiseti isolate C12	AY147368	99%								
Fusarium equisetti strain Z10	EF611087	87%	1	1			1	10	1	1
Fusarium oxysporum	AF443071	>99%		2			1	2		
Fusarium oxysporum isolate FO-02	AY928409	99%								
Fusarium oxysporum isolate FO-07	AY928414	>99%	4					1		
Fusarium proliferatum NRRL31071	EF453150	98%	1				1			
Fusarium proliferatum strain NRRL 43667	AF291061	99%		1						
Fusarium solani	AM412642	89%	3	4				17	1	
Fusarium solani strain FRC#s43	DQ094686	>99%	3					1		
Fusarium solani strain NRRL32483	DQ094448	91%								
Fusarium sp. F13	EF055302	98%						3		
Fusarium sp. IBL 03152	DQ682576	99%			1				2	
Fusarium sp. IBL 03156	DQ682579	>99%			1		16	1		
Fusarium sp. NR-2006-M41	DQ480359	99%						1		
Fusarium sp. P002	EF423517	>99%	1	1			1	3	1	
Fusarium sp. SA1-1	EF601626	99%		12						
Fusarium sp. SA4-2 (c)	EF601627	97%		1			1	13		
Fusarium sp. SA6-3(1)	EF601632	>99%		6				1		
Fusarium sporotrichioides isolate 05-15755C1	EF464168	98%		4						
Gibberella pulicaris	DQ132833	>99%						2		
Metarhizium anisopliae strain NHJ5858	AY646369	>99%								
Metarhizium anisopliae strain NHJ6195	AF218207	99%	2		1					
Mortierella alpina	AM262444	98%	7		3		7	2	2	
Mortierella elongata	AJ878504	96%		1	5		3	6		
Neosartorya quadricincta NRRL 2154	AF459730	98%				1				
Paecilomyces lilacinus strain MD1	DQ641505	98%	1	14	1		1	3	1	
Penicillium citrinum	DQ682589	98%					11			
Penicillium glabrum	DQ682590	91%			4					
Penicillium granulatum isolate 732	DQ681334	>99%					1			
Penicillium pulvillorum starin NRRL 2026	AF178517	95%			1					
Penicillium sp. CC54/5b	AY345343	>99%			1					
Penicillium thomii strain 1	DQ132815	99%		3				1		
Pleosporales sp. EXPO538F	DQ914736	96%								1
Pseudallescheria boydii	AJ888423	97%	1							
Trichoderma aureoviride strain IMI 113135	AF194019	99%	8				5	1		
Trichoderma harzianum	AF469188	98%	16	10						
Trichoderma harzianum Ir. 561	AY154948	97%					1			
		Total fungal isolates=	53	62	18	2	72	82	8	13

* Data presented were collective numbers of three sampling dates. These data represent approximately 50% of total collected isolates that have been identified. Molecular identification for the remaining 50% isolates is in progress.

** SM = soil mounds, PD = plant debris, AE = external body region of RIFA, AI = internal body region of RIFA.

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Cellular fatty acid profile of *Bacillus sphaericus* isolated from red imported fire ants and their mounds. Sandra W. Woolfolk and Richard E. Baird. Mississippi State University, Department of Entomology & Plant Pathology, Mail Stop 9655, Mississippi State MS 39762
Sww3@entomology.msstate.edu

As a part of a large project, a study was conducted to determine bacteria that are associated with red imported fire ants (RIFA). The final goal of the project is to locate potential candidate(s) of microbial control agents for RIFA. Several strains of *B. sphaericus* have been known as biopesticides against mosquitoes. Among 2324 bacterial isolates collected, many of those were characterized as *Bacillus sphaericus* based on their fatty acid profile using gas liquid chromatograph. Cellular fatty acid profile of 87 isolates of *B. sphaericus* from RIFA was analyzed using Sherlock MIS 4.5 software. The isolates were grouped into three subgroups: *B. sphaericus* subgroup III, IV, and V, and the relationship among subgroups was presented in the dendrogram (Figure 1). Of all fatty acids extracted, 15:0 ISO was the most dominant (Table 1). As described in other studies, fatty acid analysis may be utilized to distinguish between the saprophytic and pathogenic strains of *B. sphaericus* from RIFA. When found, the pathogenic strain can be a great candidate for RIFA management – this warrants further study.

Fire ants on MS golf courses: the unseen handicap. A. Williams and J. Reed. EPP, MSU.

[Abstract not on file]

Insight into the genes of Lygus through EST's. M. L. Allen. USDA-ARS BCPRU, Stoneville.

All of an organism's genes are contained within the genome, which is composed of DNA. The genes that are being actively used by the organism are transcribed into RNA. At a given time of development, or in a specific tissue, the RNA present makes up the transcriptome. Some transcribed RNAs are translated into proteins; at a given time of development, or in a specific tissue, the proteins present make up the proteome.

While each nucleus of each cell in every stage of the insect contains at least one complete set of genomic DNA, the expressed genes (those transcribed into RNA and translated into proteins) differ in the egg, nymph, and adult stages, and between the sexes in adults and preadults.

Male nymphs were collected fresh and total RNA was extracted. Each nymph yielded around 10 micrograms of RNA. When this RNA was further purified into polyA RNA, about 2% (200 ng) of the RNA sample remained. From this, a cDNA library was constructed. Sequencing was performed by the USDA ARS in Stoneville, MS. Sequences were analyzed by comparison with the NCBI (National Center for Biotechnology Information, at the website http://www.ncbi.nlm.nih.gov) BLAST algorithms.

This study (Allen 2007) revealed many previously unknown genes for an increasingly important pest. Two hundred and seventy-two unique ESTs were generated, 48% of which could be identified as highly similar to other sequences. The average sequence length was 768 bases, with only eleven ESTs having a length less than 300 bases. Sequences less than 200 bases were not deposited as ESTs. Sequences that could be identified with some probability were categorized into six groups:

1. Transcription and translation (10% of provisionally identified sequences) including ten ribosomal proteins.
2. Cellular metabolism and physiological process sequences (15%).
3. Structural and cytoskeletal sequences (7%).
4. Sequences associated with feeding and digestion (4%).
5. Mitochondrial sequences (4%).
6. Sequences homologous to genes for which a function was not identified (8%).

The male nymph ESTs were used to identify enzymes used to break down plant cell walls, polygalacturonases (Allen *et al.* accepted). Additional ESTs from adult females are being deposited. Genes that are specific to males and females will be identified. I hope to identify genes associated with pigments and cuticle synthesis. Additional ESTs derived from salivary glands, and from developing

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embryos, will be cloned and sequenced. Salivary gland genes will be used to design plant protection tools to combat Lygus and other sucking pests.

Allen ML. 2007. Expressed sequenced tags from *Lygus lineolaris* (Hemiptera: Miridae), the tarnished plant bug. *Genetics and Molecular Research* 6: 206-213.

Allen ML, Mertens JA. accepted. Molecular cloning and expression of three polygalacturonase cDNAs from the tarnished plant bug, *Lygus lineolaris* (Hemiptera: Miridae). *Journal of Insect Science*.

Inter simple sequence repeats: Utilization of genetic markers in migratory studies of *Helicoverpa zea* in northern Mississippi. S. R. Vemula, M. A. Caprio, J. C. Schneider and F. R. Musser. EPP, MSU.

[Abstract not on file]

Sampling three-cornered alfalfa hopper nymphs in soybeans. J. Robbins and G. L. Andrews. DREC.

[Abstract not on file]

The degradation of lignocellulose by wood-feeding termites and its potential and practical values in biofuel-industries. Jian-Zhong Sun. Coastal Research and Extension Center, Mississippi State University, Poplarville, MS 39470

Lignocellulosic biomass is an attractive energy feedstock because the supplies are renewable, environment-compatible, and abundant domestically and globally. The U.S. starch-based ethanol industry will jump start a greatly expanded ethanol industry that includes cellulosic ethanol as a major transportation fuel. Thus, it is a growing demand in biofuel-industries to develop the technologies that are effective to convert lignocellulose to ethanol. However, current processes to break down biomass into simple sugars and convert them into ethanol are inefficient and constitute the core barrier to producing ethanol at quantities and costs competitive with gasoline.

Termites are among the most important and effective lignocellulose-digesting insects on the earth (see Fig. 1) and are generally divided into a lower (with protozoa symbionts) and a higher (without protozoa symbionts) termite group. Both groups of termites possess a great variety of symbiotic microorganisms in their hindguts, including Bacteria, Archaea and Eukarya. As a world smallest bioreactor, the degradation of woody lignocelluloses by wood-feeding termites is very unique and highly efficient, which demonstrates combined actions of the termite own and its hindgut microbial symbionts in the utilization of 74-99% of the cellulose and 65-87% of the hemicellulose, as well as 2-83% lignin of the ingested plant material. Two main contributions of the termite to the breakdown of lignocellulose are the provision of small wood particles and the excretion of endogenous cellulases. The utilized wood is grinded by termite mandibles to particles < 50 μm in size that would substantially increase the surface area and, therefore, the accessibility to hydrolyzing enzymes. In the biological conversion of cellulose to glucose at least three distinctive types of glycolytic enzymes are involved, i.e. endoglucanases (EG, EC 3.2.1.4), cellobiohydrolases (CBH, EC 3.2.1.91), and β-glucosidases (BGL, EC 3.2.1.21), which are also found from wood-feeding termites. The lower termites, such as *Coptotermes formosanus* Shiraki, demonstrate a dual cellulose-degrading system for an effective lignocellulosic decomposition, one in the salivary glands, midgut where cellulose digestion is accomplished by endogenous cellulases (termite origin) and the other in the hindgut which makes use of other cellulases generated from symbiotic flagellates (symbiotic origin). However, it should be noted that potential hydrolyzing activities against crystalline cellulose are always higher in the symbiont-packed hindgut even when compared to the high potential activities in the salivary glands. It is, thus, suggested that hindgut symbiotic microorganisms would play a substantial role in a dual cellulose-degrading system in the lower termites. A similar situation is also observed for xylan, the most abundant hemicellulose in wood. The main activity of endo-β-1, 4-xylanase and β-xylosidase responsible for hemicellulose decomposition are primarily origins from symbiotic microorganisms in termite hindguts. Except fungus-growing termites, most of wood-feeding

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termites are not efficient in lignin decomposition (< 20%) due to the anaerobic environment in their majority parts of hindguts.

The potential and practical values of wood-feeding termites in the biofuel-industries could be summarized in the followings:

1. The passage of the wood particles through the digestive tract of a wood-feeding termite only takes < 24 h, which is more efficient bioconversion in degrading lignocellulose than wood-rotten fungi. Therefore, further studies of this extraordinary gut ecosystem may also lead to novel biotechnological applications in cellulose ethanol.
2. The symbiosis between termites and the gut flora can be described as a synergistic interaction of termite origin enzymes and of microbial origin enzymes. This dual enzymatic system secures a higher rate of hydrolytic processes of cellulose and hemicellulose. Therefore, termites and their guts could serve as an excellent and extraordinary reservoir to screen and identify an array of lignocellulolytic microorganisms or their genes to meet the needs and the improvements in a large scale of bioconversion from biomass.
3. Significant amount of energy gases, H_2 and CH_4, are produced as the byproducts from the digestion of wood by termites. A colony of *C. formosanus* (a wood-feeding lower termite species) could potentially release 87-94 liters H_2/day/10,000 termites, with this approach; termite guts could be practically used as the world smallest bioreactors to generate a large scale of biological H_2 at an effective, economic and viable pathway.
4. Sequencing and cloning work on termite or its symbionts' genes associated with lignocellulolytic activities has already shown promising applications in bio-ethanol and bio-hydrogen industries.

In this presentation, an outlook is made for the present progress in understanding termite digestive systems and particularly how we can possibly with termites harness the pathways towards biofuel industries.

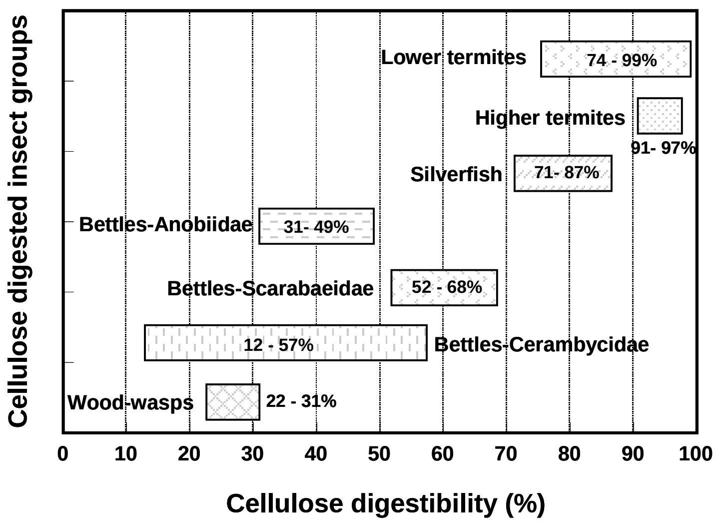

Fig. 1. Cellulose digestion in some insects (modified from Pins R. A. and Kreulen, D. A. 1991)

Effect of NI artificial diet modifications on the fitness parameters of mass-reared *Lygus hesperus* Knight (Hemiptera: Miridae). M. Portilla and D. Streett. ARS-USDA, Stoneville.

[Abstract not on file]

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