Appendix A. – Major accomplishments of S-1017 and its extension SD-339

The progress toward goals is documented in publications by the technical committee members and their graduate students or cooperators. Results from all states or agencies are often used by pecan growers across the southern U.S. after interpretation by specialists in the cooperative extension services in each state. Technical committee members often have split appointments between research, extension and teaching. Therefore, research results, extension information and educational materials prepared as theses by graduate student are found in the references cited in this section.

For Objective 1. Improve systems for monitoring pecan arthropod pests.

The sex pheromone of the monophagous *Acrobasis nuxvorella* Neunzig (Lepidoptera: Pyralidae) was reported as (9*E*,11*Z*)-hexadecadienal (9*E*,11*Z*-16:Ald) (Biorg. Med. Chem. 4: 331–339, 1996), and it has since been an effective integrated pest management (IPM) tool for monitoring this pest in the United States, but not in Mexico. Field and laboratory studies were conducted to confirm that the species in Mexico was indeed *A. nuxvorella* and to investigate the pheromone chemistry of the Mexican populations of this species. Initial field trials testing compounds structurally related to the known pheromone component, and blends thereof, indicated that a 100 μg:100 μg blend of (9*E*,11*Z*)-hexadecadien-1-yl acetate (9*E*,11*Z*-16:Ac):9*E*,11*Z*-16:Ald in rubber septa was effective in attracting male moths in Mexico. Coupled gas chromatography-electroantennogram analyses confirmed the presence of these compounds in extracts of pheromone glands of females, and antennae of male moths also responded to the alcohol analog (9*E*,11*Z*)-hexadecadien-1-ol (9*E*,11*Z*-16:OH). Subsequent field trials of various blends of these three compounds in Mexico showed that 1) both the acetate and aldehyde components were required for optimal attraction of male moths of the Mexican populations, and 2) addition of the alcohol suppressed attraction of males in a dose-dependent manner. Tests with the 1:1 9*E*,11*Z*-16:Ac:9*E*,11*Z*-16:Ald blend at various sites in the United States showed that this blend attracted some moths, but that moths attracted to 9*E*,11*Z*-16:Ald alone were predominant in the population. Furthermore, in preliminary studies the latter seemed not to respond to the blend. These findings indicate that there are two pheromone types of the pecan nut casebearer

Many hours are dedicated to scouting pecan aphid populations in pecan orchards. Population models with both a deterministic and stochastic components were developed to describe the population dynamics of pecan aphids (Matis et al 2006) from a large dataset collected from pecan orchards. The models provide predictive equations for aphid abundance. Honeydew production by blackmargined aphid was measured in the field with water-sensitive cards commonly used for measuring pesticide spray patterns. The quantity of honeydew was positively correlated to the aphid density and the honeydew was attractive to predatory insects. The method may be useful for quantifying aphid abundance in pecan orchards esp. where the foliage is out of reach. Three pecan cultivars had different amounts of honeydew and the cost to the tree in loss of photosynthate was compared to the benefit of attracting predators for each cultivar. ‘Cheyenne’ lost the most photosynthate and during certain sampling dates had the highest number of predatory insects. The aphid abundance on ‘Cheyenne’ was higher than on the other cultivars (Honaker 2007).

Pecan weevil is a major fruit pest of pecan (Mulder & Grantham 2007) that feeds on the shuck as an adult and also punctures the shell to oviposit on the kernel. Evidence of a mechanism that restricts oviposition was inferred from observations in a highly infested orchard that multiple feeding punctures were common, whereas, multiple oviposition punctures were rare (Smith and Mulder 2009). Movement by pecan weevil adults, emerging from the orchard floor, to the pecan tree and movement within and between trees is poorly understood. Additionally, no information exists on diel periodicity of pecan weevil movement. Cottrell and Wood (2007, 2008) found no interaction between trap location and sex for pecan weevils using any of four different trap styles. More pecan weevils were found to crawl to the trunk than fly and a proportion of the population flies directly into the pecan canopy. In three of four years, adult pecan weevils were vertically distributed similarly throughout the pecan canopy and most pecan weevils captured in flight were from the highest traps suspended between trees. In addition, they report for the first time on the diel periodicity of movement of pecan weevils from the orchard floor to the trunk where it was found to be a predominantly crepuscular event taking place at dusk. A study of the population genetics of the pecan weevil indicated that there are distinct populations of the weevils in different locations across the U.S. Locations in western and eastern states and in locations in north/central and southern states as well as in eastern sites on either side of the Appalachian Mountains each have distinct populations of pecan weevil (Mynhardt 2006). Post harvest detection of pecan weevil infested pecans was improved to 74-84% positive detection and ID of pecan nutmeats in the shell with pecan weevil infestations with the development of a multispectral analysis system where nuts scanned under four different wavelengths of electromagnetic radiation (Shah 2006).

A new trap was developed to measure the seasonal occurrence *Xyleborus ferrugineus* (F.) and other coleopteran borers of pecan trees . The ethanol-baited traps were tested in commercial orchards of five counties of northern Coahuila, Mexico. These inexpensive traps were made of 600-ml plastic water bottles filled with 300 ml of 50% ethanol, which caught as much as 10 times more insects than yellow sticky traps in preliminary observations. The most abundant beetle was *X. ferrugineus*, with 93% occurring from July to October, suggesting a multivoltinism for this species. Occurrence of *X. ferrugineus* from December to May was practically zero, indicating a dormancy of the insect during this period. Other beetles caught in the traps the buprestids *Chrysobothris* sp. and *Agrilus* sp.; the cerambycids *Neoclytus acuminatus* (F.), *Megacyllene caryae* (Gahan), *Oncideres cingulata* (Say), and *Saperda* sp.; and the bostrichid *Xylobiops* sp. (Aguilar-Perez et al 2007).

The black pecan aphid causes economic damage through feeding on pecan foliage that can lead to leaf abscission and tree defoliation when aphid populations are high. Damage symptoms typically appear as chlorotic zones on pecan foliage that eventually turn brown as the leaf tissue dies. Here we studied the nature of the interaction between the black pecan aphid and the chlorosis it causes to pecan foliage. In laboratory experiments, we found that a significantly higher percentage of black pecan aphid adults and nymphs settled on chlorotic leaf discs than on non-chlorotic leaf discs indicating that the chlorotic zones on leaves are attractive to the black pecan aphid. Indeed, when we tested young aphid nymphs for their ability to develop on leaf discs, nymphs that were allowed to feed on the same leaf disc which had increased chlorosis over time had lower mortality and developed faster than nymphs that were transferred to new leaf discs without chlorosis each day. These results show that black pecan aphid-induced leaf chlorosis plays an important role in the interaction of the black pecan aphid with its pecan host Cottrell et al 2009). The feeding of the black pecan aphid elicits different levels of enzyme activity in susceptible and resistant pecan cultivars. Susceptible cultivars have higher peroxidase enzyme activity than resistant cultivars after feeding by the black pecan aphid. Lipoxygenase enzymes were induced by aphid feeding in resistant and not susceptible pecan cultivars. This research may lead to better understanding of the mechanism that pecan trees have for resisting the attack of black pecan aphid (Chen et al 2009).

For Objective 2. Improve control systems for pecan arthropod pests.

Tebufenozide and chlorpyrifos were evaluated in the laboratory for toxicity to different developmental stages (eggs, larvae, and/or adults) of six predators of pecan aphids were exposed to the insecticides. Control of hickory shuckworm, *Cydia caryana* (Fitch), by the insecticides and selectivity to native predators of pecan aphids were also tested in commercial orchards. Tebufenozide had no significant adverse effect on coccinellids, but killed eggs of the lacewings *Chrysoperla rufilabris* (Burmeister) and adults of *Chrysoperla carnea* Stephens, whereas, chlorpyrifos was very toxic to all stages of chrysopids, exhibiting ovicidal activity on multicolored Asian lady beetle, *Harmonia axyridis* (Pallas). Both insecticides were effective in controlling hickory shuckworm in the field (Quinoñes-Pando et al 2009).

Outreach and extension activities took on a radical improvement for pecan stakeholders through the development of the pecan ipmPIPE - a new IPM pest information platform for extension, education and research (Harris 2010). To paraphrase Dr. Harris [Pecan IPM has been fostered for several decades by the CSREES “Southern Regional Program for Pecan Insects”, currently identified as S-1017, whose members and associates encompass CA, AZ, NM, TX, OK, KS, MO, AR, LA, MS, IL, AL, SC, GA and FL. Information technologies (IT) developed by S-1017 that reduce risk are deliverable area-wide using the USDA ipmPIPE concept via the internet. Pecan ipmPIPE platform development involves communications among producers, scientists and industry to organize IT to provide both real-time and background information needed to effectively conduct and evaluate IPM. Initially, the real-time target pest is pecan nut casebearer, which relies on a sentinel producer network (200+) for raw data input via S-1017 peer cooperators that is synthesized, enhanced and redistributed area-wide. Real-time IT will be backstopped with an IPM toolbox platform component relevant to local/regional needs. Additional pests are expected to be added later as IT matures. Pecan ipmPIPE began in 2009 and links pecan stakeholders with pecan IPM education, extension and research programs and information in the southern states. This program combines IPM expertise and the real-time experience of producers with the power of web-based IT to harness knowledge needed in risk management assessment for use in near real-time on an area-wide scale.]

Current information on pesticide evaluations is available for control of hickory shuckworm (Hall and Burnham 2009a, Dutcher 2010), pecan nut casebearer (Hall and Burnham 2009b), pecan leaf scorch mite (Dutcher and Hudson 2010), and aphids (Dutcher, Karar and Abbas 2010). Extension articles on major pest problems were updated for pecan weevil (Hall 2009d), yellow aphids (Hall 2009b), stink bugs and leaffootted bugs (Hall 2009a), pecan phylloxera (Hall 2009c), pecan nut casebearer (Hallberg and Knutson 2008), and pecan spittlebug (Hall et al 2009).

Integration of chemical and biological control of pecan leaf scorch mite is now effective with bifenazate and western predatory mite (Dutcher 2007, Dutcher et al 2009)

*Meloidogyne partityla* is a parasitic nematode of pecan and walnut. Control of this plant parasitic nematode with entomophillic nematodes was marginal and inconsistent indicating that the treatments tested were sufficient for controlling *M. partityla* (Shapiro-Ilan et al 2006c).

For Objective 3. Develop biological control systems for pecan arthropod pests.

The green lacewing was found to feed and reproduce after feeding on either blackmargined aphids or black pecan aphids on infested seedling plants. The lacewings were also more abundant on trees treated with attractant/food sprays of certain combinations of wheast, caryaphollene, tryptophan (HCl), and honey. In repeated trials, the lacewings responded differently to the same treatments (Kunkel and Cottrell 2007).

The multi-colored Asian lady beetle (MALB), *Harmonia axyridis* (Pallas), was tested for preference of the three pecan pest aphids: yellow pecan aphid, *Monelliopsis pecanis* Bissell, black-margin aphid, *Monellia caryella* (Fitch), and black pecan aphid, *Melanocallis caryaefoliae* (Davis), as well as two aphid species common in the pecan system understory: crape myrtle aphid*, Lagerstroemia indica* L., and cow-pea aphid, *Aphis craccivora* Koch. Bioassays showed aphids eaten by each of the four instars of MALB larvae over time (fifteen aphids picked randomly from all four instars) of the following combinations: all aphids from the same species, five of each type of the three pecan pest aphids, and three of each of the five aphid species tested. Some significant differences were observed with the bioassays using fifteen aphids of the same species and three each of the five aphid species tested. Overall, no preferences were found between the three species of pecan aphids and crepe myrtle aphids, but there was a lower preference for cowpea aphid. This is part of a comprehensive study on ground cover management to enhance biological control and soil conditions in improved pecan orchards. A brief summary of available results on biological control and soil enhancement will also be given (Williamson 2008).

*H. axyridis* was introduced from the Far East to southern Georgia in the early 1980’s as a biological control for pecan aphids. The beetles became established in southern Georgia and northern Florida in 1992-1993. Eight to nine years afterward aphids and aphidophagous insects on pecan and crape myrtle were greatly reduced in samples collected from the same areas and at time the same plants in 2001 and 2002 as compared to 1993. In 2006, *H. axyridis* was the dominate aphid predator in North Florida and only spiders and reduviids were found in significant abundance (Mizell 2007).

The role of parasites, pathogens and parasitoids that attack lady beetles is poorly known. An exhaustive review of the scientific literature on this subject revealed that lady beetles are attacked by bacteria, fungi, mites, nematodes, protozoa, wasps and flies, but few of these enemies have the ability to alter the population dynamics of their hosts. This research also highlighted the importance of pre-release screening of lady beetles to limit human involvement in the spread of pathogens and parasites from one locality to another. Unintentional spread of pathogens could undermine the reputation and success of biological control programs (Riddick et al 2009).

Entomophillic nematodes and fungal pathogens were found the be effective biological control agents for use against pecan weevil (Shapiro-Ilan et al 2008, Shapiro-Ilan et al 2009a, 2009b).

A surfactant, Kinetic, added to aqueous suspensions of entomopathogenic nematodes had no effect on *C. caryae* suppression. In greenhouse trials, *C. caryae* larval survival was lower in all nematode treatments compared with the control, yet survival was lower in *S. carpocapsae* (Italian) and *S. riobrave* (7–12) treatments than in *S. carpocapsae* (Agriotos), *S. carpocapsae* (Mexican), and *S. riobrave* (355) treatments (survival was reduced to ~ 20% in the *S. riobrave* [7–12] treatment). A mixture of *S. riobrave* strains resulted in intermediate larval survival. In field experiments *S. riobrave* (7–12) applications resulted in no observable control, and, although *S. carpocapsae* (Italian) provided some suppression, treatment effects were generally only detectable one day after treatment (Shapiro et al 2006a).

The entomopathogenic fungi *Beauveria bassiana* (Balsamo) Vuillemin and *Metarhizium anisopliae* (Metschnikoff) Sorokin are pathogenic to and are being developed as microbial control agents for pecan weevil. The efficacy of *B. bassiana* (GHA strain) and *M. anisopliae* (F52 strain) applied to trees in orchards was measured at three locations: Byron, GA, Fort Valley, GA, and Comanche, TX. At Fort Valley, treatments included *B. bassiana* as an oil-based spray with a UV-protective screen applied to the trunk, *M. anisopliae* applied as an impregnated fiber band stapled onto the trunk, and a nontreated check. At Byron, GA, we compared the *B. bassiana* trunk treatment to a nontreated check. Treatments at the Texas location were the *B. bassiana* trunk application, *M. anisopliae* applied as a trunk band and as a soil drench, and a nontreated check. At each location, weevils were trapped and transported to the laboratory for 15 to 17 days post-treatment to record mortality and mycosis. At both Georgia locations, *B. bassiana* caused ≥80% mortality and mycosis, which was significantly greater than mortality observed in the check (≤33%); mortality and mycosis in the *M. anisopliae* treatment at Fort Valley did not differ from that observed in the check. In Texas, due to insufficient replication in plots, statistical comparison among treatments was not possible. However, mean percentages of mortality of pecan weevils after 7 and 14 days were 38 and 55% in the check, 75 and 88% in the *B. bassiana*-treated plots, and 57 and 75% in the *M. anisopliae* treated plots. These results indicate potential for *B. bassiana* trunk sprays to suppress adult pecan weevil.

*M. anisopliae* was evaluated as a trunk treatment (fiber band with live fungus) and soil treatment for control of emerging pecan weevil adults. In laboratory experiments, we found this fungus to possess high virulence (killing-power) versus pecan weevil. Significant mortality of emerging pecan weevils was observed in both years of the field tests (2005 and 2006). Although results from field trials were variable, the research indicates that trunk band or ground applications of *M. anisopliae* have potential to cause significant infection in pecan weevil populations (Shapiro-Ilan et al 2009).

Lady beetles are important natural enemies of soft-bodied insects (such as aphids) in various crops during the spring and summer. A parasitic fungus , *Hesperomyces virescens* Thaxter, was found infecting lady beetles in multiple habitats in Georgia, USA. Parasite infection increased as the relative abundance of two lady beetles (an exotic species and a native species) increased. The fungus spreads during social contact between infected and uninfected individuals. The presence of the fungal parasite may affect commercial shipment and storage of lady beetles for the biological control of pests (Riddick and Cottrell, in press).

**Major Publications of S-1017 for 2006-2010**

##### **Aguilar-Perez, H., L. A. Rodriguez-del-Bosque, C. H. Aguilar-Perez and N. Duran de la Peña. 2007.** Seasonal abundance of *Xyleborus ferrugineus* (Coleoptera: Curculionidae) on pecan trees in northern Coahuila, Mexico. Southwestern Entomologist 32(2):105-109.

**Chen, Y., X. Ni, T. E. Cottrell, B. W. Wood and G. D. Buntin. 2009**. Changes of oxidase and hydrolase activities in pecan leaves elicited by black pecan aphid (Hemiptera: Aphididae) feeding. J. Econ. Entomol. 102: 1262-1269.

**Cottrell, T.E. and B. W. Wood. 2007.** Pecan weevil movement within the orchard. Pecan Grower. 28(4):30-36.

**Cottrell, T.E., Shapiro Ilan, D.I. 2007.** Differential susceptibility of lady beetles to *Beauveria bassiana* [abstract). In: Abstracts of Ecology of Aphidophaga Conference, September 4-11, 2007, Athens, Greece. p. O37.

**Cottrell, T. E. and B. W. Wood. 2008.** Movement of adult pecan weevils *Curculio caryae* within pecan orchards. Agric. For. Entomol. 10: 363–373.

**Cottrell, T.E., B. W. Wood, X. Ni. 2008.** Initiation of leaf chlorosis benefits the black pecan aphid. Pecan Grower. 20(2):22.

**Cottrell, T.E., B. W. Wood, X. Ni. 2009.** Chlorotic feeding injury by the black pecan aphid (Hemiptera: Aphididae) to pecan foliage promotes aphid settling and nymphal development. Environmental Entomology. 38:411-416.

**Dutcher, J. D., G. Esendugue Fonsah and W. G. Hudson. 2006.** Management of insect and mite pests in pecan orchards. Recent Res. Develop. Entomol. 5: 95-109. ISBN: 81-7736-246-1. Research Signpost, Kerala, India.

**Dutcher, J. D. 2007.** A Review of Resurgence and Replacement Causing Pest Outbreaks in IPM. IN A. Cianco & K. G. Mukerji (eds.) General Concepts in Integrated Pest and Disease Management. (Integrated Management of Plant Pests and Diseases vol. 1) Springer Publishers. Dordrecht. ISBN: 1-4020-6060-1.

**Dutcher, J. D. 2007.** Impact of predatory mite releases on the abundance of pecan leaf scorch mite. J. Entomol. Sci. 42: 517-524.

**Dutcher, J. D. and G. W. Krewer. 2007**. Biology and Control of Vectors of *Xylella fastidiosa* in Fruit and Nut Crops. IN Geeta Saxena and K. G. Mukerji (eds.). Management of Nematode and Insect-Borne Plant Diseases. The Haworth Press – Taylor & Francis Group New York, London ISBN 978-1-56022-135-7. doi:10.1300/5754\_02. p.47-65.

**Dutcher, J. D. 2009.** Matching the reproductive capacity of the pest to the efficacy of the pest control method. The Pecan Grower 20(3): 24-27.

**Dutcher, J. D. 2009.** Tips for insect control in 2009. The Pecan Grower. 20(4): 50-51.

**Dutcher, J. D., H. Karar and G. Abbas. 2010.** Efficacy of two insecticides for control of foliage-feeding aphids of pecan. Arthropod Management Tests 35D: (in press).

**Dutcher, J. D. and W. G. Hudson. 2010.** Pecan leaf scorch mite control with miticides, 2009. Arthropod Management Tests 35D: (in press).

**Dutcher, J. D. 2010.** Hickory shuckworm control with insecticide sprays, 2007-2009. Arthropod Management Tests 35D: (in press).

**Dutcher, J. D., E. G. Fonsah and W. G. Hudson. 2009.** Integration of bifenazate and western predatory mite (Acari: Phytoseiidae) for control of pecan leaf scorch mite (Acari: Tetranychidae) in pecan (Fagales: Juglandaceae) orchards. J. Entomological Science. 44(2): 98-110.

**Dutcher, J. D., M. L. Wells, T. B. Brenneman, M. G. Patterson. 2010.** Integration of insect and mite, disease, and weed management to improve pecan production. IN A. Cianco & K. G. Mukerji (eds.) Integrated Management of Arthropod Pests and Insect Borne Diseases (Integrated Management of Plant Pests and Diseases vol. 5) Springer Publishers. Dordrecht. ISBN-10: 9048124638.

**Hall, M. J. 2009a.** Stink bugs and leaffooted bugs on pecans. BugBiz: Pest Management and Insect Identification Series. Pub 3134. [http://www.lsuagcenter.com/en/our offices/research stations/Pecan/Features/Entomology/](http://www.lsuagcenter.com/en/our%20offices/research%20stations/Pecan/Features/Entomology/) 2p.

**Hall, M. J. 2009b.** Yellow pecan aphids on pecans. BugBiz: Pest Management and Insect Identification Series. Pub 2546. [http://www.lsuagcenter.com/en/our offices/research stations/Pecan/Features/Entomology/](http://www.lsuagcenter.com/en/our%20offices/research%20stations/Pecan/Features/Entomology/) 2p.

**Hall, M. J. 2009c.** Pecan phylloxera. BugBiz: Pest Management and Insect Identification Series. Pub 2547. [http://www.lsuagcenter.com/en/our offices/research stations/Pecan/Features/Entomology/](http://www.lsuagcenter.com/en/our%20offices/research%20stations/Pecan/Features/Entomology/) 2p.

**Hall, M. J. 2009d.** Pecan weevil. The Delta Pecan Grower. Vol 4: 3.

**Hall, M. J. and K. S. Burnham. 2009a.** Control of hickory shuckworm in a commercial pecan orchard with selected insecticides, 2008. Arthropod Management Tests 2009, Vol. 34. doi: 10.4182/amt2009.D14.

**Hall, M. J. and K. S. Burnham. 2009b.** Control of pecan nut casebearer in a commercial pecan orchard with selected insecticides, 2008. Arthropod Management Tests 2009, Vol. 34. doi: 10.4182/amt2009D15.

**Hall, M. J., D. K. Ring, and D. K. Pollet. 2009.** Pecan Spittlebug. BugBiz: Pest Management and Insect Identification Series. Pub 1886. <http://www.lsuagcenter.com/en/communications/publications/> 2p.

**Hallberg, R. and A. Knutson. 2008.** Degree-day technology enhances options in PNC arsenal. Pecan South. May. p. 10-11.

**Harris, M. K. 2007.** Pecan Insects: Ecology and Control. IN D. E. Pimentel (ed.) Encyclopedia of Pest Management. Volume II. ISBN:  9781420053616

**Harris, M. K., A. Knutson and B. Ree. 2009a.** Pecan ipmPIPE: Pecan producers provide feedback. Pecan South. 12 (9): 23 & 33.

**Harris, M. K., J. Millar; R. Medina. 2009b**. Scientists alert growers to PNC pheromone issues. Pecan South 42 (1): 27.

**Harris, M. K. 2010.** Pecan IpmPIPE Belt-Wide Progress and Update for 2010. Proc. Southeastern Pecan Growers Assoc. (in press).

**Honaker, J. M. 2007.** Quantification of blackmargined aphid (*Monellia caryella* (Fitch)) honeydew production in pecan (*Carya illinoinensis* (Koch)) in Texas. M.S. Thesis Texas A& M University, Entomology Department. 50 p.

**Kunkel, B.A., Cottrell, T.E. 2006.** Oviposition preference by the green lacewing Chrysoperla rufilabris for blackmargined aphids on pecan. Pecan Grower. 28(1):22-25.

**Kunkel, B.A., Cottrell, T.E. 2007.** Oviposition response of green lacewings (Neuroptera: Chrysopidae) to aphids (Hemiptera: Aphididae) and potential attractants on pecan. Environmental Entomology. 36(3):577-583.

**Matis, J. H., Kiffe, T. R., Matis, T. I. and Stevenson, D. E. 2006.** Application of population growth models based on cumulative size to pecan aphids. J. Agric. Biol. Environ. Statistics 11(4): 425-449.

**Mizell, R. F. III. 2007.** Impact of *Harmonia axyridis* (Coleoptera: Coccinellidea) on native arthropod predators on pecan and crape myrtle. The Florida Entomologist 90(3): 524-536.

**Mizell, R. F. 2010.** Predicting phenology of pecan nut casebearer in north Florida. Actia. Hort. (In press).

**Mulder, P. G. and R. A. Grantham. 2007.** Biology and control of the pecan weevil in Oklahoma. Oklahoma Cooperative Extension Service EPP-7079.

**Mynhardt, G., M. K. Harris and A. I Cognato. 2007.** Population genetics of the pecan weevil (Coleoptera: Curculionidae) inferred from mitochondrial Nucleotide data. Ann. Entomol. Soc Am. 100: 582-590.

**Mynhardt, G. 2006.** Population genetics of the pecan weevil, *Curculio caryae* (Horn) inferred from mitochondrial nucleotide data. M.S. Thesis Texas A& M University, Entomology Department. 30 p.

##### **Quinoñes-Pando, F. J., S. H. Tarango-Rivero, C. A. Blanco. 2009.** Effect of two insecticides on hickory shuckworm (Lepidoptera: Tortricidae) and predators of pecan pests. Southwestern Entomologist 34(3):227-238.

**Reilly, C.C., Wood, B.W., Cottrell, T.E. 2007.** Comparison of ground and aerial application, fungicide deposition and biological activity in large pecan tree canopies. Southeastern Pecan Growers Meeting Proceedings. 100:115-123.

**Riddick, E. W., T. E. Cottrell, K. A. Kidd. 2009.** Natural Enemies of the Coccinellidae: Parasites, Pathogens, and Parasitoids. Biological Control 51 (2009) 306-312.

**Riddick, E. W. and T. E. Cottrell. 2010.** Is the Prevalence and Intensity of the Ectooparasitic Fungus Hesperomyces virescens Related to the Abundance of Entomophagous Coccinellids? Bulletin of Insectology (in press, Accepted 12.14.09)

**Shah, C. P. 2006.** Detection of pecan weevil larvae in pecan nutmeat using multispectral imaging system. M. S. Thesis. Oklahoma State University, Biosystems Engineering Department. 100 p.

**Shapiro-Ilan, D. I., T. E. Cottrell, I. Brown, W. A. Gardner, R. K. Hubbard, and B. W. Wood.** **2006a.** Effect of soil moisture and a surfactant on entomopathogenic nematode suppression of the pecan weevil, *Curculio caryae*. J. Nematol. 38: 474–482.

**Shapiro-Ilan, D. I., A. P. Nyczepir and E. E. Lewis. 2006b.** Entomopathogenic nematodes and bacteria applications for control of the pecan root-knot nematode, *Meloidogyne partityla*, in the greenhouse. J. Nematol. 38(4): 449-454.

##### **Shapiro Ilan, D.I., T. E. Cottrell, W. Gardner, R. W. Behle, A. P. Nyczepir, B. W. Wood. 2006c.** Alternative pest control tactics in pecan. Proc. SE Pecan Growers Assoc. 99:86-94.

**Shapiro-Ilan D.I., R. Stuart and C.W. McCoy. 2006d.** A comparison of entomopathogenic nematode longevity in soil under laboratory conditions. Journal of Nematology. 38:119–129.

**Shapiro-Ilan, D.I., L.A. Lacey and J. P. Siegel. 2007.** Microbial control of insect pests of stone fruit and nut crops. In: Lacey LA, Kaya HK, editors. Field manual of techniques in invertebrate pathology. Vol. II. New York: Springer.

**Shapiro-Ilan, D. I., W. A. Gardner, T. E. Cottrell, R. W. Behle, and B. W. Wood. 2008.** A comparison of application methods for suppressing the pecan weevil (Coleoptera: Curculionidae) with *Beauveria bassiana* under field conditions. Environ. Entomol. 37: 162–171.

**Shapiro-Ilan, D. I., T. E. Cottrell, W. A. Gardner, J. Leland and R. Behle. 2009a.** Mortality and mycosis of adult *Curculio caryae* (Coleoptera: Curculionidae) following application of *Metarhizium anisopliae*: laboratory and field trials. J. Entomol. Sci. 44: 24-36.

##### **Shapiro-Ilan, D. I., T. E. Cottrell, W. A. Gardner, R. W. Behle, B. Ree and M. K. Harris. 2009b.** Efficacy of entomopathogenic fungi in suppressing pecan weevil, *Curculio caryae* (Coleoptera: Curculionidae), in commercial pecan orchards. Southwestern Entomologist 34(2):111-120.

##### **Shapiro Ilan, D.I., W. A. Gardner, T. E. Cottrell, R. W. Behle, W. G. Hudson and B. W. Wood. 2009c.** A comparison of application methods for suppressing the pecan weevil using beneficial fungi. Pecan Grower. 21(1):20-24.

**Shapiro-Ilan, D. I., T. E. Cottrell, W. A. Gardner, J. Leland and R. Behle. 2009d.** Mortality and mycosis of adult Curculio caryae (Coleoptera: Curculionidae) following application of *Metarhizium anisopliae:* laboratory and field trials. J. Entomol. Sci. 44: 24-36.

##### **Shapiro Ilan, D.I., G. N. Mbata and K. B. Nguyen. 2009e.** Characterization of biocontrol traits in the entomopathogenic nematode *Heterorhabditis georgiana* (Kesah strain), and phylogenetic analysis of the nematode's symbiotic bacteria. Biological Control. 51:377-387.

**Shapiro Ilan, D.I., Reilly, C.C., Hotchkiss, M.W. 2009f.** Suppressive effects of metabolites from Photorhabdus and Xenorhabdus spp. on phytopathogens of peach and pecan. Archives of Phytopathology and Plant Protection. 42:715-728.

##### **Shapiro Ilan, D.I. 2010.** Improved biological control of pecan weevil through pre-emergence applications. Pecan Grower. 21(3):18-20.

##### **Smith, M. W. and P. G. Mulder. 2009.** Oviposition characteristics of pecan weevil. Southwestern Entomologist 34(4):447-455. 2009.

**Stevenson, D. E. and M. K. Harris . 2009** Determining circadian response of adult male *Acrobasis nuxvorella* (Lepidoptera: Pyralidae) to synthetic sex attractant pheromone through time-segregated trapping with a new clockwork timing trap. *Environmental Entomology* 38: 1690-1696.

**Tillman, P.G. Aldrich, J.R., Khrimian, A., Cottrell, T.E. 2010.** Pheromone attraction and cross-attraction of *Nezara, Acrosternum,* and *Euschistus* spp. stink bugs (Heteroptera:Pentatomidae) in the field. Environmental Entomology. 39:610-617.

**Williamson, J. R. 2008.** Encouraging Natural Defenses in Pecan Orchards. PhD. Dissertation. Department of Entomology, University of Georgia, Athens, GA 84 pp.