THE IMPORTANCE OF TAXONOMIC TRAINING TO THE EARLY DETECTION OF EXOTIC PESTS IN THE ORDER HEMIPTERA (AUCHENORRHYCHA, STERNORRHYCHA)

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Abstract

The introduction and establishment of non-native arthropods continually threatens United States agriculture, forests, and natural areas. In order to assist in the early detection of exotic pests, including arthropods, the National Plant Diagnostic Network (NPDN) was formed in June, 2002 by USDA CSREES. The NPDN promotes early detection of exotic pests through diagnostics, training and education, information technology, and response exercise scenarios. The NPDN is divided into five regions based on geography and crop similarities, and the University of Florida is the coordination center for the Southern Plant Diagnostic Network (SPDN). The NPDN primarily links land grant universities nationwide, but also seeks to communicate with USDA APHIS and state departments of agriculture as appropriate for regulated pest issues. Organization of intensive taxonomic workshops covering a broad range of topics was one of the objectives established for SPDN entomology in 2004-05. A 3-day workshop on Hemiptera (Auchenorrhycha, Sternorrhycha) was held in December, 2004. Eight national experts led the training and 30 participants from 13 states in the U.S. attended. Major outcomes of the workshop for participants included (1) improved diagnostic abilities, (2) an increased ability to network with specialists, and (3) improved diagnostic resources. The following papers by Miller, Wilson, Dietrich, and Hodges and Evans resulted from the workshop.

Key Words: National Plant Diagnostic Network, NPDN, Southern Plant Diagnostic Network, SPDN, Homoptera workshop, non-native pests

Resumen

La introducción y el establecimiento de artópodos no nativos continuamente amenazan las áreas agrícolas, forestales bosques, y naturales de los Estados Unidos. Para asistir en la detección temprana de las plagas exóticas, incluyendo los artópodos, se formo la Red Nacional de Diagnostica de Plantas (por su sigla en inglés NPDN) en junio de 2002 por el USDA CSREES. La NPDN promueve la detección temprana de las plagas exóticas por medio del diagnóstico, el entrenamiento y educación, tecnologia de información, y ejercicios de respuesta a unos casos. La NPDN esta dividida en cinco regiones basadas sobre la geografia y similitud de cultivos, y la Universidad de Florida es el centro de coordinación para la Red sureste de Diagnóstico de Plantas (SPDN). La NPDN principalmente hace el enlace con las universidades locales presentes en toda la nación, pero también busca comunicarse con USDA APHIS y los departamentos de agricultura estatales apropiados para los asuntos de plagas regularizadas. Uno de los objetivos establecidos por el SPDN en 2004-5 fue la organización de talleres taxonómicos intensivos cubriendo un rango amplio de tópicos. Se realizo un taller de 3-dias sobre insectos del orden Hemiptera (Auchenorrhycha, Sternorrhycha) en diciembre de 2004. Ocho expertos nacionales dirigieron el entrenamiento y 30 participantes de 13 Estados en los Estados Unidos participaron. Los resultados mayores del taller para los participantes incluyeron (1) el mejoramiento de sus abilidades de diagnóstico (2) un aumento en su abilidad para comunicarse con los specialistas, y (3) el mejoramiento de los recursos de diagnóstico.

The National Plant Diagnostic Network (NPDN) http://www.npdn.org/ was formed in June 2002 by the USDA Cooperative State, Research, Education, and Extension Service (CSREES) in order to promote the early detection of exotic plant pests through enhanced diagnostics, training and education, information technology networking, and response exercise scenarios. Exotic pest introductions into the U.S. and Caribbean typically occur through trade and travel patterns, but concerns relating to agricultural bioterrorism introductions also exist as evident in the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (USDA-APHIS 2002). In accordance with this act, the USDA-APHIS developed a list of select agents (initially 10, but subsequently changed to 8 when soybean rust and plum pox were de-listed) that potentially could be devastating to major U.S. commodity crops. All select agents are currently plant pathogens and

handling is considered an agricultural biosecurity issue, regulated through the USDA-APHIS -PPQ.

Many of the NPDN efforts have focused on select agent plant pathogens that are a concern from an agricultural bioterrorism perspective. Even though select agents are a priority for the NPDN, the early detection of all high-risk exotic plant pests of concern is also important. The NPDN was divided into five regions based on U.S. geography and crop similarities in order to best address exotic pest concerns. The NPDN primarily links land grant universities nationally and regionally, but also collaboratively communicates and cooperates with the USDA Animal Plant Health Inspection Service (APHIS) as well as the state departments of agriculture. The coordinating institutions, regional directors, and geographic composition of each region are shown (Table 1).

The Importance of Hemiptera (Auchennorrhycha, Sternorrhycha) as Exotic, Invasive Insects

There are several examples of exotic Hemiptera (Auchennorrhyccha, Sternorrhycha) establishing in the U.S. and causing major pest problems. In Florida, approximately 150 species of exotic arthropods established from 1986-2000 according to Florida Department of Agriculture, Division of Plant Industry (FDACS-DPI) database records, and the Auchennorrhycha and Sternorrhycha represented the most common insect grouping of these invasives (Thomas 2000). Florida, in particular, is a foothold for exotic introduction into other states as an estimated number of 15-20% of taxonomic fauna in south Florida is not native, compared to an average of 1.7% for the remainder of the continental U.S. (Ewel 1986). Several exotic Auchennorrhycha and Sternorrhchya are well suited for establishing in the subtropical climate of the southern U.S. or in the greenhouse/nursery trade, and many of these insects can attack a wide variety of economically important hosts. Early detection of all exotic insects is important to either (1) implement a localized, immediate eradication program, or (2) for proper pest management strategies to be investigated. Many exotic arthropods enter Florida and other southern states through various international trade and travel patterns, including trade with the Caribbean. The Caribbean's tropical to subtropical climate is a perfect location for the establishment of exotic Homoptera. Browning (1992) specifically mentions 30 exotic Homoptera invaders to the Caribbean that have resulted in biological control projects. There are several examples of non-native recent and historic Homoptera introductions that have caused major problems for U.S. agriculture. Some aphid, psyllid, and scale insect examples are described below.

The soybean aphid, *Aphis glycines* Matsumura, is an example of an Asian native that was first detected in July, 2000, in Wisconsin (Ragsdale et al. 2004). Subsequent to its initial detec-

TABLE 1. NPDN GEOGRAPHICAL REGIONS AND REGIONAL DIRECTOR AFFILIATIONS.

NPDN region	States/U.S. Territories	Regional Director	Organizational affiliation
Great Plains Diagnostic Network (GPDN)	Colorado, Kansas, Montana, Nebraska, North Dakota, Oklahoma, South Dakota, Texas, Wyoming	Jim Stack	Department of Plant Pathology, Kansas State University
Southern Plant Diagnostic Network (SPDN)	Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Puerto Rico, Tennessee, Texas, Virginia	Gail Wisler	Department of Plant Pathology, University of Florida
North Central Plant Diagnostic Network (NCPDN)	Indiana, Illinois, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin	Ray Hammerschmidt	Department of Plant Pathology, Michigan State University
Northeast Plant Diagnostic Network (NEPDN)	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia	George Huddler	Department of Plant Pathology, Cornell University
Western Plant Diagnostic Network (WPDN)	Alaska, American Samoa, Arizona, California, Guam, Hawaii, Idaho, Marshall Islands, Nevada, New Mexico, Northern Marianas, Oregon, Palau, Saipan, Taipei, Utah, Washington	Rick Bostock	Department of Plant Pathology, University of California-Davis

tion, it was found in 10 additional North Central U.S. states during 2000. Most soybean workers agree that the soybean aphid was probably present prior to 2000, but no samples were taken and it was not identified prior to this date. It is likely that the soybean aphid was originally mistaken for the cotton aphid, *Aphis gossypii* Glover. The U.S. has approximately 60 million acres of soybeans that potentially will be impacted by this economically important pest (Ragsdale et al. 2004; Venette & Ragsdale 2004).

The Asian citrus psyllid, *Diaphorina citri* Kuwayama, first detected in Florida in 1998, is another example of a recent invader of concern (Halbert & Manjunath 2004). The threat of the Asian citrus psyllid is in its ability to transmit pathogens that cause one of the worst worldwide diseases of citrus, known as citrus greening or "huanglongbing" disease. The organisms causing citrus greening are on the USDA's select agent list. Because the pathogen recently was detected in Florida in August 2005, the established populations of the psyllid vector and its potential to transmit citrus greening is a concern to U.S. citrus production.

Exotic scale insects (Hemiptera: Coccoidea) have a long history of causing problems in the continental United States (Miller et al. 2005). The first successful control of a pest by biological control can be attributed to cottony cushion scale *Icerya purchasi* Maskell in California (Van Driesche & Bellows 1996). Also, the U.S. Plant Quarantine Act in 1912 was, in part, initiated by the introduction and rapid spread of the San José scale, *Diaspidiotus perniciosus* (Comstock) in the late 1800s (Marlatt 1920). If not properly managed, San José scale is still a problem in stone fruit crop orchards. According to Miller, et. al. (2005), 21 species of exotic scales have become established in the continental United States over the last 20 years and at least 11 of these species are considered problematic pest. Even though several exotic scale species have been introduced and established, only approximately 14% of the 7,355 worldwide species of scale insects occur in the continental U.S. (BenDov et al. 2003). Consequently, promoting the early detection of exotic scale insects is critically important for the protection of United States agricultural commodities.

MATERIALS AND METHODS

The Formation of the SPDN Entomology Subcommittee

Due to concerns relating to select agent and high-risk plant pathogens, much of each state's funding nationwide initially involved diagnostic equipment costs related to establishing minimum laboratory capabilities. A significant proportion of funds have been devoted to the infrastructure relating to the development of a national/regional information technology network. Even though some entomologists were included in the NPDN, an overall need existed to further incorporate and develop an entomology program. To specifically address entomology-related concerns relative to mission of the SPDN, a subcommittee consisting of representation from each state was formed in the spring of 2004 (Table 2). The programs developed by the SPDN could potentially serve as a model for the further inclusion of entomology in other regions.

Objectives of the SPDN Entomology Subcommittee

The SPDN entomology subcommittee develops annual overall goals for entomology in conjunction with the mission of the SPDN and each representative also collaboratively works with their SPDN plant pathology counterparts as well as other state representatives for the submission of an annual budget plan of work. One overall regional goal developed for the 2004-05 budget included

TABLE 2. 2004-05 SPDN ENTOMOLOGY REPRESENTATIVES.

SPDN representative	Organizational affiliation
Charles Ray	Auburn University
John Hopkins	University of Arkansas
Catharine Mannion	University of Florida
Amanda Hodges, SPDN Entomology and Training/Education Coordinator	University of Florida
Keith Douce	University of Georgia
Blake Newton	University of Kentucky
Dale Pollet	Louisiana State University
Blake Layton	Mississippi State University
Steve Bambara	North Carolina State University
John Morse	Clemson University
Frank Hale	University of Tennessee
Carlos Bográn	Texas A&M University
Eric Day	Virginia Polytechnic University

enhanced taxonomic training in pest groups of concern. The SPDN subcommittee provided the following recommendations for the training: (1) several families or taxa should be covered, (2) the training should provide a brief overview for less experienced participants, (3) in order for the training to be interesting to more advanced participants, a basic skill level should be expected for everyone, (4) participants should be prepared to practice keying specimens at least to the genera-level, and possibly to the species-level in some cases, (5) much of the training should be hands-on, (6) some information on high-risk exotic pests within taxa covered should be provided, (7) regional keys would be helpful on some pest groups, (8) new material developed for the workshop could be published post-conference as a product of the training, and (9) a 3-day workshop would be optimal. In contrast to the training proposed, many previous workshops (1) focused on specific genera or families in detail and was targeted at the specialist-level, or (2) provided a general overview and mostly a family-level perspective of a large taxonomic group. Additionally, funds for coordinating or traveling to taxonomic workshops have been lacking which subsequently has resulted in few, if any, opportunities for enhanced taxonomic training. Several possible topics for training were discussed, and it was decided that training on Hemiptera (Auchennorrhycha, Sternorrhycha), referred to as the former order name 'Homoptera' for simplicity, would be conducted.

Site Selection and Planning the 'Homoptera' Workshop

Due to the extensive collection of Auchennorrhycha and Sternorrhycha located at the Florida State Collection of Arthropods (FSCA), curated by taxonomists working with the Florida Department of Agriculture and Consumer Services, Division of Plant Industry (FDACS-DPI), Gainesville, FL was selected as the location for the training session. The taxonomic specialists responsible for these groups, Susan Halbert and Gregory Hodges, agreed to lead sections of the training and coordinate use of specimens for training purposes with other specialists. The specialist instructors and their respective institutions are shown by topic in Table 3. In addition to the topics shown, Gregory Hodges offered an optional evening slide preparation session. By offering the slide preparation session in the evening, only those individuals requiring this skill-based training attended, which permitted a broader spectrum of topics to be covered during the workshop. All training was conducted at a teaching laboratory in the Entomology and Nematology Department at the University of Florida.

RESULTS

Workshop Overview

The workshop enrolled 30 participants from the University of Georgia, Syngenta, Texas A&M University, Texas Cooperative Extension, the USDA-APHIS, the University of Florida, the University of Puerto Rico, Auburn University, the University of Tennessee, Virginia Polytechnic University, Louisiana State University, Cornell University, USDA-CSREES, Rutgers University, Mississippi State University, University of Kentucky, and Clemson University. A visiting scientist from the Republic of Korea also participated in the training. Most participants were diagnosticians from land grant universities, but industry and federal agencies also were represented in the enrollment. Two applicant spaces per each SPDN state/U.S. territory were reserved initially. The remaining spaces, and any reserved enrollment spaces not used by SPDN representation, were available on a first-come, first-serve basis. Space, equipment limitations, and an appropriate instructor-to-student ratio for hands-on learning limited further enrollments.

Workshop participants were provided with approximately 1000 pages of training material. Some of the material provided to participants was compiled information used only for educational instruction during the workshop. In many other cases, specialists developed regional keys for taxa and these new materials developed for training are in the proceedings reported in this issue of Florida Entomologist.

TABLE 3. TAXONOMIC SPECIALISTS FOR THE 'HOMOPTERA' WORKSHOP BY TRAINING TOPIC.

Specialist	Organizational affiliation	Topic
Christopher Dietrich	Illinois Natural History Survey	Cicadomorpha
Gregory Evans	USDA APHIS PPQ	Aleyroidea
Susan Halbert	FDACS DPI	Aphidoidea, Psylloidea
Gregory Hodges	FDACS DPI	Aleyroidea
Douglass Miller	USDA ARS SEL	Coccoidea, Psylloidea
Gary Miller	USDA ARS SEL	Aphidoidea
Michael Williams	Auburn University	Coccoidea
Stephen Wilson	Central Missouri State University	Fulgoroidea

Workshop Outcomes

The results of an anonymous survey conducted at the conclusion of the workshop were extremely favorable. Of the respondents (n = 25), 100% indicated that the workshop training was definitely productive. Participants also were asked to name the presentation, meeting time, or topic that they found most useful during the training. Some respondents listed very specific components of the training, and several others listed a taxa group or multiple taxa groups as the most useful. The largest percentage of respondents, 48%, specifically mentioned that all training was equally useful (Fig. 1). The second and third highest responses highlighted include Coccoidea (36%) and Aphidoidea (32%), but all sessions were specifically mentioned by some of the participants. When asked how information obtained/learned at the workshop would be used upon returning to their job, a large majority (68%) of participants emphasized the value of improved diagnostic skills (Table 4). Some of the participants conduct regular identification services for county extension agents, general extension identifiers, growers, Certified Crop Consultants, and Master Gardeners. Participants also were asked to write 1-2 sentences describing the impact of the 'Homoptera' training for their program and institution. The benefit of the increased identification services that they would be able to provide following training (40%) as well as the value of the training resources such as the training manual, ScaleNet http://www.sel.barc.usda.gov/scalenet/scalenet.htm,

and other web-based resources (36%) was again emphasized by the participants (BenDov et al. 2003). Several of the participants (28%) mentioned that enhanced taxonomic training in 'Homoptera' was critical to their home institution. Finally, participants were also asked how the workshop could have been improved. The largest respondent percentage (32%) said that nothing or very little could be done to improve the workshop. Some suggestions for improvement made by multiple participants included (1) lengthen the training to 4-6 days (20%), (2) more hands-on lab time (16%), and (3) reference collections of economically important species could be provided to participants (8%).

DISCUSSION

The intensive taxonomic training on Hemiptera (Auchnorrhycha, Sternorrhycha) provided by the SPDN critically improved taxonomic identification skills for general entomology diagnosticians and extension specialists within the southern region. Subsequent to completing training, attendees have networked and communicated with specialists for confirming species-level identification of suspect or high-risk pests for at least 15 samples to date. In some cases, individuals have communicated with specialists by utilizing digital diagnosis. Samples collected by 'Homoptera' workshop participants and confirmed by specialists have included at least two new state records, several host plant records, and one continental record.
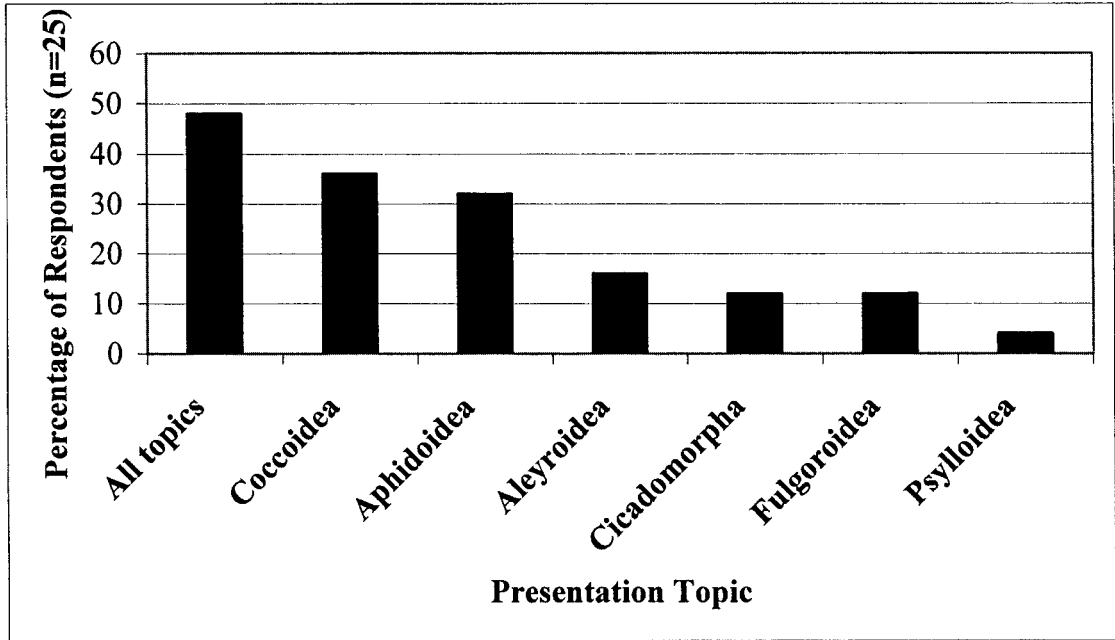

Fig. 1. Most informative topic by percentage of respondents. Multiple answers per respondent are possible.

TABLE 4. HOW WILL INFORMATION LEARNED BE UTILIZED IN YOUR JOB?[1,2]

Information learned	Percentage of Respondents (n = 25)
Improved diagnostic skills	68%
Improved my skills as a trainer	20%
Networking with specialists	16%
Improved diagnostic resources	12%
Improved early detection of exotic pests	12%
Plan to develop reference collection based on training	12%
Improved ability to provide management recommendations	8%

[1]Multiple responses per participant are possible.

[2]Responses in the table represent items listed by more than one respondent. The several items listed by more than one respondent were too numerous to include in the table.

The enhanced identification skills and the valuable networking obtained will facilitate the early detection, and possibly prevent the establishment, of exotic 'Homoptera' of concern. Additional taxonomic training on other high-risk taxa are needed to further prevent the establishment of other invasive, exotic arthropod species. For 2006, the SPDN entomology subcommittee is currently planning an intensive Coleoptera workshop with topics including bark beetles (Scolytidae), long-horned beetles (Cerambycidae), and leaf beetles (Chrysomelidae). Outcomes and suggestions for improving the 2004 'Homoptera' training will be used to optimize learning for the 2006 Coleoptera training.

ACKNOWLEDGMENTS

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