### NCERA 224 (previously 193) IPM Strategies for Arthropod Pests and Diseases in Nurseries and Landscapes, 2015 chair and report author, Vera Krischik, Department of Entomology, University of Minnesota, 612.625.7044, krisc001@umn.edu

**Members of NCERA 224 that regularly attend meetings, contact information**

1. Dave Smitley, Entomology, Michigan State University, East Lansing, MI smitley@msu.edu

2. Gary Chastagner, Plant Pathology, Washington State University, Puyallup, WA chastag@wsu.edu

3. Chris Williamson, Entomology, University of Wisconsin, Madison, WI, rcwillie@entomology.wisc.edu

4. Eric Rebek , Entomology and Plant Pathology, Oklahoma State University, eric.rebek@okstate.edu

5. Juang-Horng “JC” Chong, Entomology, Soils, and Plant Sciences, Clemson University, Florence, SC, juanghc@clemson.edu

6. Vera Krischik, Entomology, University of Minnesota, St. Paul, MN, krisc001@umn.edu

7. Brian Kunkel, Entomology, University of Delaware Cooperative Extension, Newark, DE,

bakunkel@udel.edu

8. Jared Le Boldus, Plant Pathology, Forest Engineering, Oregon State University, Corvallis, OR

 jared.leboldus@science.oregonstate.edu

9. Randall Zondag, Entomology, OSU Extension, Lake County, [zondag.1@osu.edu](file:///C%3A%5CUsers%5Ckrisc001%5CDesktop%5C2015%20NCERA%20Feb12016%20copy%5Czondag.1%40osu.edu)

10. Heping Zhu, Entomology, USDA/ARS, heping.zhu@ars.usda.gov

11. Enrico (Pierluigi) Bonello, Plant Pathology, Ohio State University, Columbus, OH, bonello.2@osu.edu

12. Whitney Cranshaw, Entomology, Colorado State University, Boulder, CO, Whitney.Cranshaw@colostate.edu

13. Lina Rodriquez-Salamanca, Plant Pathology, Iowa State University, Ames, IA lina@iastate.edu

14. Megan Kennelly, Plant Pathology, Kansas State University, Manhattan, KS, kennelly@ksu.edu

15. Bill Jacobi, 2016 National Elm Report part of NCERA 224, Colorado State University, Boulder, CO, [william.jacobi@colostate.edu](file:///C%3A%5CUsers%5Ckrisc001%5CDesktop%5C2015%20NCERA%20Feb12016%20copy%5Cwilliam.jacobi%40colostate.edu), retired but active with the elm trial

16. Administrator: Christina Hamilton, University of Wisconsin, Madison, WI,

[christina.hamilton@wisc.edu](file:///C%3A%5CUsers%5Ckrisc001%5CDesktop%5C2015%20NCERA%20Feb12016%20copy%5Cchristina.hamilton%40wisc.edu)

17. Dan Hermes, Entomology, Ohio State University, Wooster, OH,, herms.2@osu.edu

18. Cliff Sadof, Entomology, Purdue University, [csadof@purdue.edu](file:///C%3A%5CUsers%5Ckrisc001%5CDesktop%5C2015%20NCERA%20Feb12016%20copy%5Ccsadof%40purdue.edu)

19. Administrator, Thomas Payne, Dean Agriculture, Food, Natural Resources, University of Missouri, Columbia, MO, payneT@missouri.edu

20. Administrator, Christina Hamilton, NCRA Assistant Director, University of Wisconsin, christina.hamilton@wisc.edu

 **Members of NCERA 224 that sent materials for the 2015 meeting**

Pierliugi Bonello <bonello.2@osu.edu>
Vera Krischik <krisc001@umn.edu>
Eric Rebek <eric.rebek@okstate.edu>
JC Chong <juanghc@clemson.edu>
Brian Kunkel <bakunkel@udel.edu>
Dave Smitley <smitley@msu.edu>
Gary Chastagner <chastag@wsu.edu>
Chris Williamson <rcwillie@entomology.wisc.edu>
Randall Zondag <Randall.Zondag@lakecountyohio.gov>
Heping Zhu <Heping.Zhu@ars.usda.gov>

Bill Jacobi <[william.jacobi@colostate.edu](file:///C%3A%5CUsers%5Ckrisc001%5CDesktop%5C2015%20NCERA%20Feb12016%20copy%5Cwilliam.jacobi%40colostate.edu)>, retired but active with the elm trial

**Administrators**

Tom Payne <payneT@missouri.edu> Attends meetings
Christa Hamilton <christina.hamilton@wisc.edu>

**2015 meeting:** Sept 19-22, 2015, Jackson WY and spent an additional day visiting the local USDA Forest Service and learn of their management programs for insects and diseases

**2016 meeting:** October 24-27, 2016, 20th Ornamental workshop on diseases and insects, Kanuga Conference Center, NC, <http://ecoipm.org/ornamental-workshop/>

**2015 Summary**

NCERA224 members perform research and extension for the US Green Industry which is comprised of state and federal land managers; wholesale nursery, greenhouse, and turf grass sod growers; landscape service firms such as architects, designers/builders, contractors, and maintenance firms; retail firms such as garden centers, home centers and mass merchandisers with lawn and garden departments; and marketing intermediaries, such as brokers and horticultural distribution centers.

Economic contributions of the green industry in each state of the US were estimated for 2007–2008 as total sales revenues of $176.11 billion. The industry had direct employment of 1.95 million jobs. The largest individual industry sectors were landscaping services (1,075,343 jobs, $50.3 billion), nursery and greenhouse production (436,462 jobs, $27.1 billion), and building materials and garden equipment and supplies stores (190,839 jobs, $9.7 billion) (Hodges, Alan W, Charles R. Hall, and Marco A. Palma. 2011. Economic Contributions of the Green Industry in the U S in 2007–08. HortTechnol 21(5): 628-638, http://horttech.ashspublications.org/content/21/5/628.full).

NCERA224 was formed in 1997 through the request of a merger of NCR98 (entomologists) and NCR43 (plant pathologists). Members of NCERA224 focus on Integrated Pest Management (IPM) strategies for insect and disease pests of ornamental plants in nurseries, landscapes, and urban forests. Key research and technology transfer goals of members include development, evaluation, and integration of the cultural, chemical, and biological control tactics that are the foundation of IPM programs. It is one of the few ways that researchers and extension specialists can meet and discuss data and collaborative projects. The objectives and anticipated outputs and outcomes are listed below.

The annual meeting provides a highly successful forum for entomologists and plant pathologists to discuss IPM programs for insects and diseases of ornamental plants, exchange research results and extension information, formulate complementary research objectives, establish interdisciplinary, multi-state collaborations, and avoid duplication of effort. This merger has fostered communication and facilitated interactions of entomologists and plant pathologists throughout the country, promoted awareness of regional and inter-regional arthropod and disease pest problems, fostered research collaborations to understand their potential impact and develop mitigation tactics and strategies, and resulted in workshops and other inter-state outreach programs for green industry professionals.

Below is a short summary of the 2015 discussion based on our research and extension objectives, outputs, and outcomes. By attending this yearly meeting, the spread of new information from research and extension is facilitated. Without this meeting, there would be limited discussion by ornamentalists on insect and disease problems.

**Objective 1. New and emerging pests** Michigan State University member (Dr. Dave Smitley) presented data on information on his research and outreach programs on ways to manage emerald ash borer by insecticide use.

Washington State University member (Dr. Gary Chastagner) has been working with federal, state, and nursery organizations to determine current distribution and spread of the sudden oak wilt pathogen *Phytophthora ramorum*. Since 2003, *Phytophthora ramorum* have been detected in over 50 ornamental plant nurseries in Washington State. Stream monitoring by state agencies has resulted in the detection of this exotic pathogen in about a dozen waterways in six western Washington counties since 2006.

University of Delaware member (Dr. Brian Kunkel) studied the efficacy of biorational insecticides, such as *Beauveria baasiana*, and *Metarhizium* spp., compared to conventional insecticides, such as azadirachtin, bifenthrin, Safari (dinotefuran), Discus (cyfluthrin/imidacloprid), and Mainspring (cyantranilprole) to management of red headed flea beetle (*Systena frontalis*), an emerging pest of nursery crops. Also, he compared biorational and conventional insecticides for thrips control.

**Research papers**

Conrad AO, Rodriguez-Saona LE, McPherson BA, Wood DL, Bonello P (2014) Identification of *Quercus agrifolia* (coast live oak) resistant to the invasive pathogen *Phytophthora ramorum* in native stands using Fourier-Transform Infrared (FT-IR) spectroscopy. Frontiers in Plant Science – Technical Advances in Plant Science 5: doi: 10.3389/fpls.2014.00521.

Smitley, David R., Daniel A. Herms, and Terrance W. Davis. 2015. Efficacy of soil-applied neonicotinoid insecticides for long-term protection against emerald ash borer (Coleoptera: Buprestidae). J. Econ. Entomol. doi: 10.1093/jee/tov205.

McKeever, Katie and Gary Chastagner. 2015. Community structures of root-rotting *Phytophthora* species affecting *Abies* in U.S. Christmas tree farms & screening true fir for resistance to Phytophthora root rot Page 163 In: Sutton, W., Reeser, P.W., and Hansen, E.M., tech coords. 2015. Proceedings of the 7th meeting of the International Union of Forest Research Organization (IUFRO) Working Party S07.02.09: Phytophthoras in forests and natural ecosystems. 195 p.

[http://forestphytophthoras.org/sites/default/files/proceedings/IUFRO\_Proceedings\_2014.pdf](http://forestphytophthoras.org/sites/default/files/proceedings/IUFRO_Proceedings_2014.pdf%20)

Chastagner, Gary and Marianne Elliott. 2015. Potential Impacts of the Revised APHIS *Phytophthora ramorum* domestic quarantine regulatory requirements on the spread of this exotic pathogen within Washington State. Page 91 In: Sutton, W., Reeser, P.W., and Hansen, E.M., tech coords. 2015. Proceedings of the 7th meeting of the International Union of Forest Research Organization (IUFRO) Working Party S07.02.09: Phytophthoras in forests and natural ecosystems. 195 p. [http://forestphytophthoras.org/sites/default/files/proceedings/IUFRO\_Proceedings\_2014.pdf](http://forestphytophthoras.org/sites/default/files/proceedings/IUFRO_Proceedings_2014.pdf%20)

Chastagner, Gary, M. Elliott K. Coats, G. Dermott and L. Rollins. 2015. Survey of Oomycetes found in western Washington streams. Page 38 In: Sutton, W., Reeser, P.W., and Hansen, E.M., tech coords. 2015. Proceedings of the 7th meeting of the International Union of Forest Research Organization (IUFRO) Working Party S07.02.09: Phytophthoras in forests and natural ecosystems. 195 p. [http://forestphytophthoras.org/sites/default/files/proceedings/IUFRO\_Proceedings\_2014.pdf](http://forestphytophthoras.org/sites/default/files/proceedings/IUFRO_Proceedings_2014.pdf%20)

**Objective 2. Pesticide technology development**

Another major collaborative research focus was the effects of neonicotinoid insecticides on bees. Numerous states initiated research and extension programs on bee conservation and ornamental plants. Minnesota passed in 2014 bee labeling laws that do not permit the use of systemic insecticides on plants labeled as beneficial to pollinators. This law impacts many states that grow and ship ornamentals throughout Midwest states. Michigan State University member (Dr. David Smitley) is investigating the effects of soil drenches of imidacloprid on bumblebees. University of Minnesota member (Dr. Vera Krischik) is studying the amount of residue in pollen and nectar from greenhouse and landscape applications of neonicotinoid insecticides. An extension bulletin on the toxicity of insecticides used on ornamentals was developed and emailed to the member states.

USDA/ARS, ATRU, Wooster, OH member (Dr. Heping Zhu) and The Ohio State University Extension, Lake County, OH member (Randall Zondag) are working on modifications of current spray equipment to calibrate and deliver spray volumes to plants**.** Current application technology for floral, nursery, and tree fruit crops requires excessive amounts of sprays to control pests due to a great diversity in canopy structure and leaf density. Critical innovative technology is needed to increase application efficiency and reduce uncertainties for conventional pesticide sprayers to achieve real cost benefits with new pesticide application strategies for producers, consumers and the environment. An automated variable-rate, air-assisted precision sprayer was developed to minimize human involvement in spray applications.

**Research papers**

Krischik V, M Rogers, G Gupta, A Varshney. 2015. Soil-applied imidacloprid is translocated to ornamental flowers and reduces survival of adult *Coleomegilla maculata*, *Harmonia axyridis*, and *Hippodamia convergens* lady beetles, and larval *Danaus plexippus* and *Vanessa cardui*, PLoS ONE March 23, 2015, DOI: 10.1371/journal.pone.0119133

**Objective 3.** **Pesticide alternatives** Developing elm resistance to Dutch elm disease, bark beetles, and elm leaf beetle is an interest of the group. A major outcome of the NCRA 224 collaboration in 2015 was the National Elm trial organized by Dr. Bill Jacobi of Colorado State University [http://bspm.agsci.colostate.edu/national-elm-trial/](http://bspm.agsci.colostate.edu/national-elm-trial/%20%20)  . Elm cultivars were planted in large replicated trials in a wide range of environmental conditions across the US so that their growth and performance could be evaluated. NCERA 224 members planted 18 commercially available elm cultivars in 15 states that were managed for 10 years. The ten year evaluations were posted on the web, <http://bspm.agsci.colostate.edu/people-button/faculty-new/william-jacobi/national-elm-trial/> . From the research a summary publication is being prepared. Elm preservation groups, such as Tom Zetterstrom of Elm Watch Community Forestry have become advocates of the trials and the data that were produced.

Washington State University member (Dr. Gary Chastagner) continues to evaluate biological control agents for suppression of *Phytophthora ramorum* in potting mixes in a nursery environment. The objective of this project was to test the effectiveness of selected commercially available biocontrol organisms to prevent the spread of *P. ramorum* in and from potting mixes in a nursery environment.

Ohio State University member (Dr. Pierluigi Bonello) is working on understanding mechanisms of ash resistance to emerald ash borer, coast live oak to *Phytophthora ramorum* (sudden oak death), and Austrian pine to *Diplodia sapinea* (Diplodia tip blight and canker), in the latter case also when trees are subject to drought conditions.

**Research papers**

National Elm Trial, collaboration of NCERA members <http://bspm.agsci.colostate.edu/national-elm-trial/>

Villari C, Herms DA, Whitehill JGA, Cipollini DF, Bonello P (2015). Progress and gaps in understanding mechanisms of ash resistance to emerald ash borer, a model for wood boring insects that kill angiosperm trees. (Invited Tansley Review.) New Phytologist

 - DOI:10.1111/nph.13604.

Sherwood P, Villari C, Capretti P, Bonello P (2015). Mechanisms of induced susceptibility to Diplodia tip blight in drought-stressed Austrian pine. Tree Physiology 35: 549-562.

Rigsby CM, Showalter DN, Herms DA, Koch JL, Bonello P, Cipollini DF (2015). Physiological responses of emerald ash borer larvae to feeding on different ash species reveals putative resistance mechanisms and insect counter-adaptations. Journal of Insect Physiology 78: 47-54.

Whitehill JGA, Rigsby C, Cipollini D, Herms DA, Bonello P (2014) Decreased emergence of emerald ash borer from ash (*Fraxinus* spp.) treated with methyl jasmonate is associated with induction of general defense traits and the toxic phenolic compound verbascoside. Oecologia 176: 1047-1059.

Rollins, L., Elliott, M., and Chastagner, G. 2015. A new method to apply *Phytophthora ramorum* inoculum to hosts that simulates overhead irrigation. Plant Health Progress doi:10.1094/PHP-RS-15-0008.

McKeever, K, and G. Chastagner. 2015. A survey of *Phytophthora* species causing root rot on *Abies* in U.S. Christmas tree farms. APS Abstract 134-O. <http://www.apsnet.org/meetings/Documents/2015_meeting_abstracts/aps2015abO155.htm>

Chastagner, G., V. Talgø, and K. Riley. Neonectria-canker on true fir in western USA. The International Forestry Review. 16(5): 2014 (Abstract).

Leon, A. L., K. P. Coats, and G. A. Chastagner. 2015. Quantification and determination of inoculum threshold levels of *Fusarium commune* in Douglas-fir nurseries. APS Abstract 73-P.

<http://www.apsnet.org/meetings/Documents/2015_meeting_abstracts/aps2015abP565.htm>

Garfinkel, A. R., and G. A. Chastagner. 2015. Not just *Botrytis*: multiple fungal pathogens cause leaf spots on peony in the United States. APS Abstract 157-O.

<http://www.apsnet.org/meetings/Documents/2015_meeting_abstracts/aps2015abO153.htm>

Garfinkel, A. R., K. P. Coats, M. R. Wildung, and G. A. Chastagner. 2015. Whole-genome sequencing of *Botrytis paeoniae* using the Ion Proton platform for microsatellite discovery. APS Abstract 780-P.
<http://www.apsnet.org/meetings/Documents/2015_meeting_abstracts/aps2015abP674.htm>

Dugan, F. M., S. L. Lupien, C. Vahling-Armstrong, G. A. Chastagner, and B. K. Schroeder. 2015. Novel reports of *Penicillium* spp. causing blue mold on onion and garlic in the Pacific Northwest U.S.A.. APS Abstract 494-P. <http://www.apsnet.org/meetings/Documents/2015_meeting_abstracts/aps2015abP206.htm>

Objective 4. Technology transfer

**Websites**

National Elm Trial, collaboration of NCERA members <http://bspm.agsci.colostate.edu/national-elm-trial/>

WSU National Elm Trial (<http://www.puyallup.wsu.edu/ppo/elm/>)

WSU Sudden Oak Death Program (<http://www.puyallup.wsu.edu/ppo/sod/>)

WSU Pacific Madrone Research (<http://www.puyallup.wsu.edu/ppo/madrone/>)

Multistate emerald ash borer website ([http://www.emeraldashborer.info/)](http://www.emeraldashborer.info/%29)

UMinn NCIPM webinars website+pollinator+plant videos  <http://ncipmhort.cfans.umn.edu/>

UMinn CFANS CUES website [cues.cfans.umn.edu/](http://cues.cfans.umn.edu/)

UMinn extension greenhouse, nursery, and landscape website
[www.extension.umn.edu/garden/plant-nursery-health/](http://www.extension.umn.edu/garden/plant-nursery-health/)

**Extension-outreach publications**

Chalker-Scott, L.,Elliott, M., Collman, S., and Antonelli, A. 2015. Identifying, treating, and avoiding Azalea and Rhododendron problems. WSU Extension Bulletin 1229.

Garfinkel A.R. and Chastagner, G.A. 2015. When it rains, it pours: Tracking *Botrytis* infection during the Alaskan peony growing season. Spring/Summer 2015 Alaska Peony Grower’s Society Newsletter.

Chastagner, G.A. 2015. Yahoo! News, USA Today, MSN, Huffington Post, The Guardian, The Denver Post, and Fox TV. Cut tree care recommendations, coauthored by with Eric Hinesley at NCSU was also widely disseminated by the National Christmas Tree Association, a number of state Christmas tree organizations, growers, and media sources.

Lee, Dong Woon, David R. Smitley, Sang Myueong Lee, Harry K. Kaya, Chung Gyoo Park, and Ho Yul Choo. 2014. Seasonal phenology and diurnal activity of *Promachus yesonicus* (Diptera: Asilidae), a predator of scarabs on Korean golf courses.

Krischik, Vera. 2015. Toxicity to pollinators of insecticides used in greenhouse, nursery, and landscapes, <http://www.extension.umn.edu/garden/plant-nursery-health/>

Krischik, Vera. 2015. New federal, EPA and Minnesota labelling laws for protecting pollinator, MNLA Scoop Newsletter, 4 pp.

Krischik, Vera. 2015. Using degree days, IRA numbers, and new online bulletins. Minnesota Christmas Tree Growers March.

[Krischik, Vera. 2015. Leatherjackets and mole crickets in turf. Hole Notes Magazine, MN Golf Course Superintendents Association](http://C:/Users/krisc001/Desktop/Krischik%2C%20Vera%20A.%202015.%20Leatherjackets%20and%20mole%20crickets%20in%20turf.%20Hole%20Notes%20Magazine%2C%20MN%20Golf%20Course%20Superintendents%20Association)

Chong, J.-H. 2015. False oleander scale, *Pseudaulacaspis cockerelli* (a.k.a. magnolia white scale). The South Carolina Nurseryman. May/June 2015, pp. X-Y.

Chong, J.-H. 2015. Wax myrtle scale, *Melanaspis deklei*. The South Carolina Nurseryman. January/February 2015, pp. 32-33.

Chong, J.-H. 2014. New insecticides for the turf market. South Carolina Sod Producers Association Newsletter. December 2014.

Robayo Camacho, E., and J.-H. Chong. 2014. Florida wax scale, *Ceroplastes floridensis*. The South Carolina Nurseryman. November/December 2014, 18-19.

Chong, J.-H. 2014. Brother, can you spare a fall armyworm? South Carolina Sod Producers Association Newsletter. October 2014.

Chong, J.-H. 2014. Scale insects: The banes of ornamentals. The South Carolina Nurseryman. September/October 2014, pp. 26-28.

Williamson R. C. and P. J. Liesch. Homeowner Guide to Emerald Ash Borer Treatments Factsheet. <http://labs.russell.wisc.edu/pddc/files/Fact_Sheets/FC_PDF/Homeowner_Guide_to_EAB_Insecticide_Treatments.pdf>

Williamson R. C. and P. J. Liesch. <http://labs.russell.wisc.edu/pddc/files/Fact_Sheets/FC_PDF/Professional_Guide_to_EAB_Insecticide_Treatments.pdf>Professional Guide to Emerald Ash Borer Treatments Factsheet.

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**Individual State reports**

**Michigan State University report to NCERA 224**

**Dr. Dave Smitley**

The results from two screen cage experiments with bumble bees are shown below. In the first experiment,’ ***Impact of imidacloprid drench of potted annual flowers on bumble bees’*** one bumble bee (*Bombus impatiens* from BioBest) colony was placed into each of 16 screen tents filled with six types of popular annual flowers: petunia, verbena, geranium, marigold, portulaca, salvia and begonia. These flowers were their only source of pollen for three weeks. The potted annuals in half of the screen tents had been drenched with imidacloprid five weeks prior to the start of the experiment. Potted annuals in the other half of the screen tents were drenched with water. Bumbles bees in each colony were marked and counted throughout the summer.

The number of bees per colony declined rapidly in both treatments. Cold weather in early June and a major thunderstorm with high winds did not help their initial establishment. Also, when compared with the excellent survival of the bumble bees in the next experiment when *Tilia* trees were put into the screen cages with the bees, it is likely that the six species of annual flowers in this experiment did not provide adequate pollen and nectar for the bumble bees. Still, recovery from the screen-tent exposure period was better for colonies in the control treatment compared with the imidacloprid drench treatment

In the second experiment, ‘**Impact of an imidacloprid basal drench applied to base of container-grown *Tilia* trees in early July 2014, on bumble bees caged with the same trees in June 2015’** *Tilia americana* and *Tilia cordata* trees were grown in pot-in-pot containers at the Horticulture Farm at Michigan State University. Half of the trees received a basal soil drench of imidacloprid, applied at the labeled rate in early July, 2014, after the trees had finished blooming and most of the flowers had dropped. Approximately one year later, the *Tilia* trees were moved into screen tents on June 15, 2015, when they first started blooming. One bumble bee colony was placed into each screen tent at this time, and remained in the tents for 10 days. Bumble bees were counted weekly or biweekly for the rest of the summer, until August 27th.

Imidacloprid drenches made in early July 2014 had no impact on the number of bumble bees per colony throughout the growing season, or on the number of queens produced per colony at the end of the summer (Figure 2). Control colonies average 7.8 queens per colony, while colonies in the imidacloprid treatment averaged 5.8 queens per colony.

**Conclusions**

Poor survival of bumble bees after being caged with annual flowers for three weeks limits the conclusions that can be made from the first experiment, which gave similar results in a 2014 experiment. However, failure of the bumble bee colonies in the imidacloprid drench treatment to recover from the stress created by screen-tent enclosure suggests that drenching flowers which are attractive to bees in the spring of the same year that they are sold could be harmful to bees.

Also, poor survival of bumble bees in screen tents with 6 of the most popular types of annual flowers, while survival was excellent when bees were caged with *Tilia* trees, highlights the importance of understanding the relative attractiveness of flowering plants to bees.

Excellent survival of bumble bees after being confined with *Tilia* trees which had been treated the previous year with an imidacloprid drench suggests that treatments made a year before trees are sold are not harmful to bees. Good queen production in both treatments supports this conclusion.

As research continues on how to produce greenhouse and nursery plants that will be safe for pollinators after they are sold and planted in the yard and garden, it is becoming increasing clear that growers and tree care professionals should focus their efforts on understanding which plants that are highly attractive to bees. In an extensive observational study conducted with more than 1,000 visits to Longwood Gardens and other gardens, none of the top 20 annual flowers grown in greenhouses across North America were rated higher than 2 on a scale of 1 to 5 for their attractiveness to bees (Lindtner 2014). This means that they are not good pollen or nectar sources for honey bees, and are only visited when better options are not available. However many perennials, trees and shrubs are highly attractive to bees. For these plants it is important not to spray them with any insecticide the last three weeks before shipping, and to avoid soil applications of a systemic insecticide in spring of the same year that they are sold.

Lindtner, P. 2014. Garden Plants for Honey Bees. Wicwas Press, LLC, Kalamazoo, MI. 396 pp.

**Recent Publications:**

Smitley, David R., Daniel A. Herms, and Terrance W. Davis. 2015. Efficacy of soil-applied neonicotinoid insecticides for long-term protection against emerald ash borer (Coleoptera: Buprestidae). J. Econ. Entomol. doi: 10.1093/jee/tov205.

Lee, Dong Woon, David R. Smitley, Sang Myueong Lee, Harry K. Kaya, Chung Gyoo Park, and Ho Yul Choo. 2014. Seasonal phenology and diurnal activity of *Promachus yesonicus* (Diptera: Asilidae), a predator of scarabs on Korean golf courses.

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**Washington State University report to NCERA 224**

**Dr. Gary Chastagner**

**A survey of *Phytophthora* species causing root rot of *Abies* in U.S. Christmas tree farms**

(McKeever and Chastagner). Multiple *Phytophthora* species are known to cause root rot (PRR) on true firs (*Abies spp.)*. Information about the community structures and habits of these regionally-variable pathogens has received little study in the past 30 years. A contemporary survey could update literature with current pathogen and host ranges; reveal previously unreported *Phytophthora*-fir combinations; and inform about varying host susceptibilities leading to improved management advice. 32 Christmas tree farms were visited in 7 U.S. states representing 4 major production regions to isolate and identify *Phytophthora* species causing disease on true firs. Symptomatic tissues from lesion margins on roots and crowns were plated on PARPH-cV8 selective media to recover *Phytophthora*. Cultures were identified by DNA sequencing of the nuclear ITS and mitochondrial *cox* I regions. It was determined that *P. cambivora* is the prominent PRR species in western WA and OR, while *P. cinnamomi* was prevalent in CA and NC. In the eastern US, the undescribed *P.* taxon ‘*kelmania’* was isolated in great frequency and was found to be capable of killing fir species considered to be tolerant of PRR. Completion of Koch’s Postulates confirmed pathogenicity of 12 unpublished *Phytophthora*-fir combinations. Supplementing established knowledge regarding *Phytophthora* species prevalence and *Abies* sensitivities will enhance crop productivity by improving recommendations for site modifications including water abatement and proper host species deployment.

**Screening *Abies* for resistance to *Phytophthora* root rot** (McKeever and Chastagner). *Phytophthora* root rot (PRR) causes significant losses in bare-root conifer nurseries and Christmas tree plantations. True fir trees are common hosts of *Phytophthora*, and popular Christmas tree species such as noble fir (*Abies procera*), Fraser fir (*A. fraseri*) are particularly susceptible. A complex of *Phytophthora* species are collectively recognized as causal agents of PRR, and vary regionally among U.S. production regions. There are limited methods available to growers for controlling PRR, but efficacy varies depending on geographic region, host species, field topography, and prior land uses. For these reasons, efforts to identify fir trees that display resistance to PRR under variable environmental conditions are justified to alleviate losses.

A large-scale greenhouse resistance screening study challenged one-year-old seedlings of 7 species of fir with 3 virulent genotypes from each of 4 species of *Phytophthora*. The *Phytophthora* isolates employed in the study were collected from fir roots during a nationwide sampling effort of tree plantations in 5 major U.S. Christmas tree production regions. In order to adequately test host performance over a range of environmental conditions, the experiment was conducted simultaneously in two greenhouses set to two different temperatures. The cool weather greenhouse was maintained at a temperature range of 15 - 21°C to replicate prevailing conditions in temperate regions such as the Pacific Northwest (PNW). The warm weather greenhouse was sustained in the 26 - 32°C range to simulate the southeastern U.S. and California. Although species such as Nordmann fir (*A. nordmanniana*) and Turkish fir (*A. bornmuelleriana*) are traditionally considered to be more tolerant to PRR than the highly susceptible noble and Fraser firs in the PNW, evidence has shown that these species are apt to fail in other growing regions with different environmental conditions and *Phytophthora* communities. The design of this study is intended to address these anomalies.

Plant material was randomized into each greenhouse in a split-split block design and inoculated by inserting colonized rice grains into the growing media. Mortality was rated weekly, and at 13 weeks all surviving seedlings were re-inoculated in the same manner. The experiment is expected to continue for an additional 5 weeks; at which time, root rot ratings and moisture content calculations should provide insight as to which seedlings qualify to be considered on the spectrum of resistance.

Tissue from resistant trees will yield genetic material appropriate for genomics testing in pursuit of molecular markers associated with resistance. It is also intended that individual trees will be conserved for future breeding applications. The goals of this study are to supplement established knowledge regarding *Phytophthora* species virulence and *Abies* sensitivities, and to enhance crop productivity by providing growers with resistant planting stock.

**Field assessment of Turkish fir tolerance to five root-rotting *Phytophthora* species.** (Mckeever and Chastagner). Turkish fir has been observed to display superior tolerance to root rot disease caused by *Phytophthora* spp. A field trial was performed to generate data to support observations of resistance to *Phytophthora* and to gauge the performance of individual seed sources collected during a 2011 seed collection trip in Turkey. The field trial employed 36 seed sources of Turkish fir collected along an elevation gradient from 3 Turkish provinces, as well as 2 seed sources of Nordmann fir and 1 North American source each of noble and Fraser firs. Inoculum consisted of a mix of 5 species of *Phytophthora* including *P. cinnamomi, P. cambivora, P. cryptogea, P. pini,* and *P. cactorum*. The goals were to assess Turkish fir susceptibility in comparison to noble, Nordmann, and Fraser firs, to compare susceptibility of the 3 provinces of Turkish fir, to look for elevation trends in susceptibility within each province, and to determine if evidence existed for host specificity between various *Phytophthora* spp. and various *Abies* spp. It was determined that while mortality of the noble and Fraser firs quickly reached 100%, the highest mortality of any Turkish fir seed source was less than 25%. One seed source of Nordmann fir suffered less than 20% mortality while the other seed source was resistant during both years of the field trial. Differences between susceptibility of the pooled seed sources from the three provinces was evident with the Bolu province exhibiting the highest mortality. There were no statistical differences in susceptibility along the elevation gradients within the Bolu and Karabuk provinces, but the lowest elevation within the Sakarya province showed statistically higher mortality. When assessing evidence for host specificity between the various *Phytophthora* spp. used and *Abies* species, it was evident that the likelihood for recovery of any *Phytophthora* species was equivalent on each *Abies*; however, mortality in on all host species in this field trial was clearly dominated by *P. cryptogea,* and *P. cinnamomi* was found more frequently on Turkish fir than on Fraser, noble, or Nordmann firs. This study provides data to support observations indicating that Turkish fir displays resistance to *Phytophthora* and provides resolution to determine superior seed sources and provenances for root rot tolerance.

**Grovesiella and Neonectria canker – Two diseases of *Abies* in the Pacific Northwest United States**

(Chastagner, Riley, Coats, and Talgø). A number of true firs are commercially grown as Christmas trees, used in landscaping, used for bough production, grown for timber and/or occur naturally in the Pacific Northwest (PNW) states of Washington, Oregon, and Idaho in the United States. The fungi *Grovesiella abieticola* and *Neonectria neomacrospora* cause canker diseases on true firs in the PNW. Neonectria.canker is also an emerging problem on true firs in Scandinavia. Symptoms of both diseases typically consist of dead shoots, cankers with heavy resin flow and distal overgrowths, branch flagging and occasionally mortality when cankers completely girdle stems. *Grovesiella* typically produces characteristic small, gray-black apothecia on the canker's surface, while characteristic red perithecia are occasionally found on cankers produced by *Neonectria*. *Grovesella* canker appears to have a more limited host range than Neonectria canker, which was found on 16 hosts in WA and OR during a survey of trees in the PNW in 2013. White fir (*A. concolor*) and shasta fir (*A. magnifica* var. *shastensis)*, are very susceptible to Grovesiella canker and support high levels of sporulation. *Grovesiella* has been observed on seedlings in nurseries and trees in Christmas tree plantations and landscape plantings. *N. neomacrospora* appears to be limited to trees in Christmas tree plantations and landscape plantings in the PNW. Limited information is available relating to factors that affect the development of these diseases, and management is currently limited to cultural practices, such as sanitation.

***Risk of Adelges (Dreyfusia) nordmannianae surviving on cut Nordmann fir Christmas trees and boughs*** (Chastagner, Riley, and McReynolds). In Europe where Nordmann fir is widely grown for Christmas trees and boughs, the silver fir woolly adelgid [Adelges (Dreyfusia) nordmannianae] is a serious pest on this host. Although not common, this pest has been observed on Nordmann fir trees at several locations in western Washington. During the past few years, data has been collected on its rate of spread and life cycle in plantings at Puyallup. Information about host susceptibility and the effectiveness of insecticide treatments in controlling this pest have also been collected.

In an effort to determine the risk that adelgids could be spread from one location to another via the movement of infested cut Christmas trees or boughs, experiments were done in 2013 and 2014 to examine the potential for adelgids to survive on harvested boughs. Branches from five heavily-infested Nordmann fir trees were utilized during this test. Three sets of branches, consisting of a single branch from each tree, were harvested in December/January. One set was stored in ventilated plastic crates outdoors. The remaining two sets were displayed indoors at 20C for about 5 weeks. One set of the displayed branches was displayed with their bases in water and the other set was displayed dry. Following the indoor display period, both sets of the displayed branches were placed in ventilated plastic crates and stored outdoors with the other branches. Checks consisted of branches that were tagged, but not harvested from the tree. The effect of these different display and storage conditions on adelgid survival was determined by periodically examining the branches to determine the viability and life stages of the adelgids through early April.

There was no evidence of mortality of the overwintering adelgids on the unharvested branches on the trees. They started laying eggs in March and crawlers were evident by early April, which was about 3 weeks prior to bud break. In 2013, the adelgids on the harvested branches that were displayed indoors in water laid eggs which hatched, producing crawlers during the indoor display period. By the end of the display period, there was no evidence of live stem mother adelgids, eggs or crawlers on any of the branches that were displayed dry. No eggs were ever found on the branches that were originally cut and stored outdoors. By mid-March to early April, there were no surviving adelgids on any of the harvested branches, suggesting that there is virtually no risk of spreading the silver fir woolly adelgid from one area to another via cut trees or boughs.

***Does the severity of current season needle necrosis decrease on older stands of noble fir?*** (Chastagner, Landgren, and Nielsen). Current season needle necrosis (CSNN) is a poorly understood disease on true firs grown for Christmas trees in Europe and North America. Early research suggested that CSNN was likely a physiological disorder that was associated with calcium deficiency and environmental stress. However, recent research in Norway has found that the endophyte *Sydowia polyspora* may play a role in the development of this disease. In the U.S. Pacific Northwest (Oregon, Washington, and Idaho) and British Columbia, CSNN is most commonly seen on noble and grand fir grown at low elevation sites. Similar needle damage has also been observed on white fir, Nordmann fir and Turkish fir. In Europe, CSNN has also been observed on grand and noble firs, but the greatest economic impact has been on Nordmann fir, the dominant Christmas tree species in Denmark and Norway.

Since 2004, the yearly severity of CSNN has been evaluate on noble fir trees in a series of genetic trials planted at WSU-Puyallup. This is a low elevation (10 to 30m) site that is very conducive to the development of CSNN and has provided an opportunity to examine yearly variation in development of CSNN and determine the variation in resistance to this disease among the different sources of trees in these trials. Unlike most trials where data was only collected annually for a few years, data were collected over an 8 year and 10 year period for trials that were established in 2002 and 2004, respectively. These 2002 and 2004 replicated plantings contained 25 trees from 35 and 53 sources, respectively. Annually, starting 2 years after planting, the severity of CSNN on each tree was rated on a scale of 0 to 10, where 0 = no CSNN, 1 = 1-10%, 2 = 11-20%, 3 = 21-30%, …., and 10 = 91-100% of the current season foliage damaged by CSNN.

Data from these longer term evaluations indicated that there was a trend of reduced damage as trees aged in the 2002 trial. In the 2004 planting, there was a significant negative correlation between the age of trees and the severity of CSNN. While the reasons for this decrease is unclear, it may lead to a better understanding of the etiology of this disease.

***Postharvest moisture status and quality of trees displayed in tenon-type Christmas tree stands.*** (Chastagner and McReynolds).Displaying Christmas trees in water holding stands has been shown to be an effective way of maintaining tree freshness, minimizing needle loss and reducing fire hazards associated with displayed trees. Water uptake during display is influenced by a number of factors, including tree species, the moisture content of the tree when it is set up, the temperature and relative humidity of the display area, how long it has been since the base of the tree was cut, the water-holding capacity of the stand, and the care the tree receives during display.

During the past few years, there has been an increased use of tenon-types of water-holding stands to display table-top trees in the United States. These stands have been used in Europe for a number of years and the concept behind them is to use a commonly available cutter to shave the end of the stem down to a uniform sized tenon that varies in length and diameter depending on the cutter that is used. The tenon is then inserted into a receptacle in the stand. In the U.S., table-top trees are sold already attached to the stand. Consumers select a tree, take it home and add water to the stand.

During the past two years, we have conducted postharvest display trials with noble, Fraser, and Nordmann fir table-top trees to determine what effect tenon stands have on their freshness and quality. Trees with freshly-cut bases that were displayed directly in water maintained high moisture level and quality ratings throughout the 10 to 14 day trials. However, trees that were displayed in the water-filled tenon stands had similar moisture levels and quality ratings to trees that were displayed without water. These trees dried rapidly and by 7 to 10 days, they had dried to the point that they posed a fire hazard. Results from these trials indicated that displaying trees in water-holding, tenon-type stands was a very ineffective way of maintaining the freshness and quality of displayed trees.

**Effectiveness of hot water dips in eliminating slugs on exported Christmas trees.** (Chastagner, DeBauw, and McReynolds).In the United States, the Pacific Northwest (PNW) region leads the nation in the production of Christmas trees. Over 90% of the trees produced are either shipped throughout the U.S. or exported to a number of foreign countries. For example, in 2012 the Oregon Department of Agriculture and Washington State Department of Agriculture issued 2,349 and 66 federal phytosanitary certificates, respectively. Trees were shipped to 17 countries, with the bulk going to: Mexico (2,243), Canada (42), Hong Kong (41), Japan (17), and Singapore (18). A total of 283 container loads were also shipped to Hawaii.

Although most exported trees are mechanically shaken prior to shipping to reduce the risk of certain “hitchhikers” such as yellowjackets and slugs, the presence of slugs on exported trees has become a major issue in Mexico and Hawaii. In addition to mechanical shaking of unbaled trees, there has been some interest in using a “hot water shower” treatment that was developed to treat potted plants that are infested by an invasive coqui frog (*Eleutherodactylus coqui*) to rid trees of slugs. In 2012, 25% of the 67 quarantined containers that were treated in Hawaii were given a “hot water shower” at 47.7C for 8 minutes. While this hot water treatment appeared promising, the system was very labor intensive and costly.

In 2013 and 2014, a series of trials were conducted to examine the effectiveness of hot water dips in killing slugs on Christmas trees. Slugs were immersed in water that was heated to temperatures between 34.4 to 51.1C for periods between 15 seconds and 12 minutes. Checks consisted of slugs immersed in water at 12.8C. Noble fir and Douglas-fir branches were also included in these tests to determine if the treatments had any adverse effects on the foliage. The shortest exposure duration/temperature that resulted in 100% mortality of all the slugs was 30 seconds at 47.7C. A 2 minute exposure was required at 41.1C to kill all of the slugs. Damage was only observed on branches that were exposed to >44.4C for more than 2 minutes. These data indicated that short-duration hot water dips could be used to reduce the risk of spreading slugs on exported Christmas trees.

***Variation in postharvest needle retention characteristics of Turkish and Trojan fir populations from Turkey*.** (Chastagner, Kurt, Frampton, Isik, and Landgren). Postharvest needle retention is an important attribute of Christmas trees. Previous studies with Nordmann fir have shown that needle retention is under strong genetic control and that progeny from open-pollinated trees with superior needle retention also tend to exhibit the same characteristic. In 2010, cones and branches were collected in Turkey from three Turkish fir populations (Adapazarı-Akyazı, Bolu-Aladağ and Karabük-Keltepe) and two Trojan fir (*A. equi-trojani*) populations (Çanakkale-Çan and Balıkesir-Kazdağı) as part of the international Collaborative Fir Germplasm Evaluation (CoFirGE) Project. Collections were made from 20 different trees, representing a range of elevations within each population, during the first week of October. As much as possible, cone-bearing trees showing good Christmas tree form and growth traits and spaced at least 100 meters from one another were selected to reduce relatedness. In addition to collecting cones and making a number of measurements on each of the mother trees at the time of cone collection, 4 branches were collected from each tree. The branches were collected from the upper third of the crown where each had good exposure to sunlight. To assess differences in needle retention among the trees, subtending lateral branches (“tongues”) were harvested from each branch. These were transported to Ankara and displayed without water in a room that was maintained at about 20 °C. After 10 days, the branches were gently rubbed between fingers three times and the severity of needle loss for each age class of needles (2009 and 2010) was rated according to the following scale: 0 = no needle loss, 1 = < 1%, 2 = 1-5%, 3 = 6-15%, 4 = 16-33%, 5 =34-66%, 6 = 67-90% and 7 = 91-100% needle loss.

Needle loss ratings among the individual trees from the Adapazarı-Akyazı, Bolu-Aladağ and Karabük-Keltepe Turkish fir populations ranged from 0 - 6.8, 0 - 6.3, and 0 - 5.6, respectively. The ratings for the Çanakkale-Çan and Balıkesir-Kazdağı Trojan fir populations ranged from 0 - 5.6 and 0 - 3.6, respectively. The percentage of trees within each population that had needle loss ratings <1 ranged from 35 to 50.5%. There was no difference between elevation and needle loss ratings among any of the populations of trees. This baseline data will be compared with future needle loss data collected from the progeny growing in U.S. and Denmark in common garden studies.

***Growth and postharvest needle retention characteristics of balsam fir grown in western Washington.*** (Chastagner, McReynolds, and Riley). In 2008, a replicated common garden field trail was established at the Washington State University Research and Extension Center in Puyallup, WA to evaluate the growth and postharvest characteristics of 26 provenances of balsam fir (*A. balsamea*) and eight progeny collections of ‘bracted’ balsam fir (*A. balsamea* var*. phanerolepis)*. A single source of Fraser fir was included in the trial as a standard. Seed was obtained from the Canadian Forest Service’s National Tree Seed Center (NTSC) and P+2 seedlings were out-planted in February of 2008 in a 0.44 ha plot at 1.8 m x 1.8 m spacing. The plot design was a randomized complete block with five blocks. Five trees of each source were planted in a row within each block. To obtain information on adaptability to growing conditions in western Washington, data were collected on growth, bud break growing-degree days (GDD), and color. Tree form and commercial grade were assessed in 2014, and were used to estimate the wholesale value of each tree. During fall 2012 and 2014, two branches were harvested from each tree and displayed dry to determine the postharvest needle retention characteristics of each tree. Needle loss was rated on a scale of 0 (none) to 7 (91-100% loss).

All of the balsam sources broke bud prior to Fraser fir and there was a significant differences in bud break GDD among the balsam sources. In 2014, tree heights ranged from 1.5 to 2.1 m and there was no significant difference in foliage color. Seed source had a significant effect on the estimated commercial value of trees. Average values by seed source ranged from $14.74 to $27.34. There was considerable variability in value within regional seed sources. Four of the five highest value seed sources and four of the five lowest value five seed sources were from New Brunswick. The average 2012 and 2014 needle loss ratings for the seed sources ranged from 1.4 to 4.0. Although trees from the NTSC No. 20021377 seed source were among the top five when rated for value, this source from Fairview, New Brunswick had the highest needle loss rating.

Even though WSU Puyallup is outside of the natural range of balsam and “bracted” balsam firs, this study indicates that there are sources of these species that are well adapted for the production of Christmas trees in western Washington. Given that a seed source with a high tree value did not always have acceptable postharvest needle retention, care needs to be taken when selecting seed sources in order to insure the best tree quality as well as profitability.

**Sudden Oak Death**

**Potential Impacts of the Revised APHIS *Phytophthora ramorum* Domestic Quarantine Regulatory Requirements on the Spread of this Exotic Pathogen within Washington State** (Chastagner and Elliott). Since 2003, *Phytophthora ramorum* have been detected in over 50 ornamental plant nurseries in Washington State. Stream monitoring by state agencies has resulted in the detection of this exotic pathogen in about a dozen waterways in six western Washington counties since 2006. Genotype analysis indicates that the NA1, NA2, and EU1 clonal lineages of *P. ramorum* are present in nursery and waterways. In all cases, streams have tested positive for *P. ramorum* in subsequent years after the first detection. Although *P. ramorum* has not been detected in a forest landscape in Washington State, in the spring of 2009, infested ditch water resulted in the infection of salal (*Gaultheria shallon*) plants by the NA2 lineage along the perimeter of a positive nursery in Pierce County. Composite soil samples collected from along the ditch were also positive in 2010. In addition, positive soil has also been detected at 3 trace forward sites where infected plants from a nursery in Thurston County had been planted in urban landscape sites. Effective March 31, 2014, the USDA Animal and Plant Health Inspection Service (APHIS) revised regulatory requirements relating to the interstate movement of host nursery stock from nurseries located in *P. ramorum* regulated and quarantine areas in California, Oregon, and Washington went into effect. These revisions have resulted in a reduction in the number of nurseries being inspected in Washington, which has the potential to result in an increase in the spread of *P. ramorum* within the state.

**Phytophthora ramorum detected at a Kitsap County, WA botanical garden (Chastagner and Elliott).** A sample from a mature Pieris plant at a 150 acre Kitsap County, WA botanical garden that had been submitted to the WSU Puyallup Plant Clinic was found to infected with *P. ramorum*. Under the direction of the USDA, regulatory sampling was conducted on the suspect Pieris plant, as well as other plants around the botanical garden. As a result of delimitation surveys, the *P. ramorum* on the Pieris was confirmed and additional infections on rhododendrons, Camelia and *Vinca minor* (a new host) were confirm at a total of 7 different sites at the garden. Based on the fact that a number of the infected plants have been in the landscape for more than 10 years, it appears that *P. ramorum* has been spreading at this site. All infected plants were destroyed and trace-back investigations have not identified the source of the infection. The garden has undergone a Critical Control Point Assessment (CCPA) at which time best management practice (BMP) mitigations will be identified for implementation. Steam treatment of the soil at the 7 positive sites is underway. The garden staff will be implementing best management practices throughout the nursery as well as taking required precautionary steps near the positive sites. A follow-up survey is planned for early fall.

**Testing biological control agents for suppression of *Phytophthora ramorum* in potting mixes in a simulated nursery environment** (Chastagner and Elliott). The objective of this project was to test the effectiveness of selected commercially available biocontrol organisms to prevent the spread of *P. ramorum* in and from potting mixes in a nursery environment. Three biocontrol treatments (*Bacillus subtilis, Trichoderma atroviride,* and no biocontrol), four potting mixes (mixtures of peat, compost, bark, and perlite), and three host plants (rhododendron, camellia, viburnum) were tested in various combinations. Colonized leaf inoculum of *P. ramorum* was buried 1 cm beneath the soil surface in each pot 1 week after biocontrol treatments were applied. Leachate from pots was collected monthly and baited for *P. ramorum* over a 6 month period. Two trials of this experiment were completed at the NORSDUC facility in San Rafael, CA.

The results from trial 2 support those from trial 1 showing that *P. ramorum* inoculum can increase in overwintering potted plants, irrespective of other treatments such as potting mix composition and treatment with biocontrol agents. This has implications for overwintering plants in nurseries, where the risk of *P. ramorum* establishment may be increased. In both trials logistic regression analysis showed a significant relationship between number of times pots were positive for *P. ramorum* and potting mix type. There were no significant relationships with biocontrol treatments and host plants. A spatial effect was seen, with a slight difference in number of times pots were positive for *P. ramorum* by block, although this was not as strong as in trial 1. Potting mix #1 was the most suppressive for all hosts, biocontrol agents, blocks, and sampling times. This mixture had 50% peat, 25% compost, 25% perlite, and 0% bark. While potting mix#2 showed the most root growth of plants, it had the highest levels of *P. ramorum* positives during both warm and cool periods. Root growth in plants grown in potting mix #4 was almost as high as those in potting mix#2, and this treatment had the fewest *P. ramorum* positive pots. There was no effect of biocontrol agent on the number of pots positive for *P. ramorum*, although there was a trend showing more visible symptom development on plants without biocontrol treatments in the soil during Trial 1.

 **Potting mixes used in trial 2 and their properties.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment #** | **Peat** | **Perlite** | **Compost** | **Redwood sawdust (tr 2)** **or fir bark (tr 1)** | **pH** | **EC** |
| 1 | 50% | 25% | 25% | 0% | 5.78 | 0.84 |
| 2 | 0% | 25% | 25% | 50% | 6.71 | 1.04 |
| 3 | 25% | 0% | 50% | 25% | 6.84 | 1.56 |
| 4 | 25% | 25% | 25% | 25% | 6.36 | 0.59 |

**Effectiveness of biofilters for removing inoculum of *P. ramorum* and other *Phytophthora* spp. from contaminated nursery water** (Elliott and Chastagner)**.** The installation of a pilot biofiltration system at a nursery that had *P. ramorum* positive water in their retention pond was completed in 2014. Some preliminary data on *Phytophthora* species present in the pond and adjoining ditch was collected before installation of the biofiltration system. Materials for the two biofilters (slow sand filter and bioretention mix containing 60% sand, 20% peat, 20% compost) were selected based on research on the removal of *Phytophthora ramorum* from various combinations of organic materials and slow sand filtration, using materials with similar hydraulic properties to the bioretention soil mixes being evaluated for removal of pollutants from stormwater runoff at WSU. Wetland plants installed in the vegetated submerged bed were chosen from stock being sold at the nursery and the planting is being used as a display area for these plant species. The plants will be evaluated for their effectiveness in removing *P. ramorum* inoculum from water. A multiprobe sonde was deployed in August 2015 to take continuous measurements of water quality variables, and several locations in the treatment system are being sampled for *Phytophthora* spp. on a monthly basis. Samples from July and August 2015 were negative for *Phytophthora* spp. in outflows from the biofilters and constructed wetland. Phytophthoras were detected in the sediment ditch and pond, as well as a ditch adjacent to the road opposite the wetland.

**Stream monitoring for invasive *Phytophthora* species on the northern Olympic Peninsula, WA** (Elliott and Chastagner). The primary goal of the project was to expand the monitoring of streams in northern Olympic Peninsula region for *P. ramorum*. In spring 2013 a bait sample positive for *P. ramorum* was collected from the Dungeness River near Sequim, WA. A second positive bait sample from this site was collected in summer 2013. Further sampling of streams in the area in 2014 did not provide information about the source of inoculum contaminating the Dungeness. The site where the positive sample was found had no apparent direct water connection with a *P. ramorum* positive nursery and the source of inoculum was unknown.

Volunteers from the community increased the level of monitoring activity in a high risk watershed where the pathogen is exposed to native vegetation beyond what was possible to accomplish by state and federal agencies, and also provided an excellent opportunity to increase public awareness about invasive plant pathogens such as *P. ramorum*. No *P. ramorum* was found after intensive sampling in Feb – May 2015, so streams in the Sequim area can be considered “free” of *P. ramorum*. Some baseline information about other *Phytophthora* speciesin these streams was collected.

In addition to sites in the Sequim area, one urban lake, two stormwater retention ponds, and two sites in an adjoining creek in Pierce County were monitored to determine whether landscaped areas in new developments may contain oomycete pathogens. This provided educational opportunities for local high school and college students in spring and summer 2015.

**Steaming as a method of eradicating *Phytophthora ramorum* and associated *Phytophthora* species in Washington State ornamental plant nurseries** (Chastagner and Elliott).There is great interest in the use of steam to treat soil infested with *Phytophthora* and other pathogens, pests, and weeds, as an alternative to chemical fumigation. Nurseries with *P. ramorum* positive soil can take advantage of this treatment method, thus reducing the risk of pathogen movement in contaminated soil. Used containers are another critical control point where diseases may infest nursery crops, and cleaning these containers is often overlooked in nursery production. Steaming may prove to be a labor-saving and less costly means to disinfect containers that will be re-used. Steaming of used media is another application of this technique that growers have expressed interest in.

Extensive steaming was done at a positive *P. ramorum* nursery that had opted-in to the revised Federal Order. Steaming of soil, pots, and potting media at this nursery occurred from August 2014 to September 2014. Although post-steaming soil samples were negative for *P. ramorum*, additional plants were detected again at this nursery in 2015. Additional mitigation steps, including the steaming of two hoophouses and piles of used containers, and nursery staff training are underway at this site. About four weeks of soil steaming has also been done at the positive botanical garden. This steaming required the development of a PVC pipe system to deliver steam to remote sites that were up to 280’ away from the steamer. Pre and post-steaming soil samples have been collected at all of the sites and will be used to confirm the effectiveness of the steaming treatment. Data is also being collected to determine whether steaming infested nursery soil, pots, and media is economically a viable option in WA State.

**Ornamental Bulb Crops**

**Not just *Botrytis*: multiple fungal pathogens cause leaf spots on peony in the United States.**

(Garfinkel and Chastagner). The herbaceous peony (Paeonia lactiflora) is grown as a high-value cut flower crop and landscape plant worldwide. Through interactions with peony growers, we found that many perceive Botrytis gray mold as a significant production and post-harvest issue at their farms. In a survey to determine the cause of leaf spots on peony, we acquired infected foliage from commercial growers and through visual scouting of peony plantings throughout the United States with an emphasis on Washington, Oregon, and Alaska. Using morphological and molecular methods, we identified multiple fungal pathogens never before reported on peony in the United States in addition to the commonly-reported pathogens, Botrytis, Cladosporium, and Alternaria. The discoveries of one of these pathogens, Mycocentrospora acerina, in Washington and Alaska represent only the second and third reports of this pathogen infecting peony in the world. The detection of Pilidium concavum in North Carolina is the first report of this pathogen on peonies outside of East Asia. We also identified a complex of Botrytis species infecting peony, of which at least one species is undescribed and appears to be unique to Alaska peony production. Clearly, a wider range of fungal pathogens, including multiple species of Botrytis, infect peony than is indicated in the common literature, such as extension bulletins and growers’ guides. These diseases are going misdiagnosed by growers, potentially hindering disease management.

**Whole-genome sequencing of Botrytis paeoniae using the Ion Proton platform for microsatellite discovery** (Garfinkel, Coats, and Chastagner). *Botrytis paeoniae* is a putatively host-specific pathogen that causes Botrytis gray mold on peony (*Paeonia* spp.). The decreasing cost of high-throughput next-generation sequencing technologies makes whole-genome sequencing of non-model organisms a cost-efficient option for aid in microsatellite marker development. For this purpose, 250 nanograms of high quality genomic DNA of *B. paeoniae* was used to construct an Ion Proton sequencing library. DNA fragments were sequenced on a single Ion Proton P1 chip to produce 10.4 gigabases of raw reads. Reads were assembled into 11,756 contigs, the longest of which was 165 kilobases. The sum of contigs totaled 44.4 megabases, similar in size to published assembled *B. cinerea* genomes. 4,746 repetitive regions were identified in the assembled genome using the default parameters in QDD v3.1.2, of which 3,614 were unique. Primer3, executed within QDD, was used to identify 3,336 microsatellite sequences for which primers could be developed. Primers will be designed for selected loci and tested on several populations to identify a panel of informative genetic markers for future analysis of *B. paeoniae*. To our knowledge, this represents one of the first fungal organisms sequenced using the Ion Proton technology for the purpose of microsatellite repeat discovery.

**Novel reports of Penicillium spp. causing blue mold on onion and garlic in the Pacific Northwest U.S.A..** (Dugan, Lupien, Vahling-Armstrong, Chastagner, and Schroeder). Single isolates of *Penicillium albocoremium, P. crustosum, P. expansum, P. glabrum*, and *P. paraherquei*, identified by morphology and DNA beta-tubulin sequences, were inoculated to garlic (*Allium sativum*) and two varieties of onion (*A. cepa*, Gold Pearl and Forum) in a design of sample size n = 3 for each of 3 replications with identical mock-inoculated controls and a single repeat. Rates of lesion expansion were compared to controls. Pencillia were re-isolated from treatments but not mock-inoculated controls. Inoculations with *P. polonicum* served as positive controls. All isolates originated from bulb crops in Washington State, except for *P. glabrum* from an onion in Idaho. In paired T-tests or GLM pair-wise comparisons, *P. albocoremium, P. crustosum, P. glabrum*, and *P. polonicum* were pathogenic to both varieties of onion (P ≤ 0.05). *Penicillium albocoremium, P. glabrum, P. paraherquei* and *P. polonicum* were pathogenic on garlic (P ≤ 0.03). Tests failed to indicate consistent pathogenicity to garlic for *P. crustosum* and *P. expansum*. On onion, *P. expansum* and *P. paraherquei* were consistently pathogenic only on Gold Pearl (P ≤ 0.04) or Forum (P ≤ 0.03), respectively. *Penicillium expansum* has been reported on onion, anecdotally, in the Pacific Northwest and *P. polonicum* has also been previously reported there; otherwise these reports appear geographically novel.

**Publications, Presentations, Workshops and Field Tours**

**Publications Since 2014 NCERA 224 Meeting**

Rollins, L., Elliott, M., and Chastagner, G. 2015. A new method to apply *Phytophthora ramorum* inoculum to hosts that simulates overhead irrigation. Plant Health Progress doi:10.1094/PHP-RS-15-0008.

Chalker-Scott, L., Elliott, M., Collman, S., and Antonelli, A. 2015. Identifying, treating, and avoiding Azalea and Rhododendron problems. WSU Extension Bulletin 1229.

Chastagner, G., V. Talgø, and K. Riley. Neonectria-canker on true fir in western USA. The International Forestry Review. 16(5): 2014 (Abstract).

McKeever, K, and G. Chastagner. 2015. A survey of *Phytophthora* species causing root rot on *Abies* in U.S. Christmas tree farms. APS Abstract 134-O.

<http://www.apsnet.org/meetings/Documents/2015_meeting_abstracts/aps2015abO155.htm>

Leon, A. L., K. P. Coats, and G. A. Chastagner. 2015. Quantification and determination of inoculum threshold levels of *Fusarium commune* in Douglas-fir nurseries. APS Abstract 73-P. <http://www.apsnet.org/meetings/Documents/2015_meeting_abstracts/aps2015abP565.htm>

Garfinkel, A. R., and G. A. Chastagner. 2015. Not just *Botrytis*: multiple fungal pathogens cause leaf spots on peony in the United States. APS Abstract 157-O.
<http://www.apsnet.org/meetings/Documents/2015_meeting_abstracts/aps2015abO153.htm>

Garfinkel, A. R., K. P. Coats, M. R. Wildung, and G. A. Chastagner. 2015. Whole-genome sequencing of *Botrytis paeoniae* using the Ion Proton platform for microsatellite discovery. APS Abstract 780-P.
<http://www.apsnet.org/meetings/Documents/2015_meeting_abstracts/aps2015abP674.htm>

Dugan, F. M., S. L. Lupien, C. Vahling-Armstrong, G. A. Chastagner, and B. K. Schroeder. 2015. Novel reports of *Penicillium* spp. causing blue mold on onion and garlic in the Pacific Northwest U.S.A.. APS Abstract 494-P. <http://www.apsnet.org/meetings/Documents/2015_meeting_abstracts/aps2015abP206.htm>

Gary Chastagner and Marianne Elliott. 2015. Potential Impacts of the Revised APHIS *Phytophthora ramorum* domestic quarantine regulatory requirements on the spread of this exotic pathogen within Washington State. Page 91 In: Sutton, W., Reeser, P.W., and Hansen, E.M., tech coords. 2015. Proceedings of the 7th meeting of the International Union of Forest Research Organization (IUFRO) Working Party S07.02.09: Phytophthoras in forests and natural ecosystems. 195 p. http://forestphytophthoras.org/sites/default/files/proceedings/IUFRO\_Proceedings\_2014.pdf

M. Elliott, G. Chastagner, K. Coats, G. Dermott and L. Rollins. 2015. Survey of Oomycetes found in western Washington streams. Page 38 In: Sutton, W., Reeser, P.W., and Hansen, E.M., tech coords. 2015. Proceedings of the 7th meeting of the International Union of Forest Research Organization (IUFRO) Working Party S07.02.09: Phytophthoras in forests and natural ecosystems. 195 p. http://forestphytophthoras.org/sites/default/files/proceedings/IUFRO\_Proceedings\_2014.pdf

Katie McKeever and Gary Chastagner. 2015. Community structures of root-rotting *Phytophthora* species affecting *Abies* in U.S. Christmas tree farms & screening true fir for resistance to Phytophthora root rot Page 163 In: Sutton, W., Reeser, P.W., and

Hansen, E.M., tech coords. 2015. Proceedings of the 7th meeting of the International Union of Forest Research Organization (IUFRO) Working Party S07.02.09: Phytophthoras in forests and natural ecosystems. 195 p. http://forestphytophthoras.org/sites/default/files/proceedings/IUFRO\_Proceedings\_2014.pdf

A.R. Garfinkel and Chastagner, G.A. 2015. When it rains, it pours: Tracking *Botrytis* infection during the Alaskan peony growing season. Spring/Summer 2015 Alaska Peony Grower’s Society Newsletter.

Yahoo! News, USA Today, MSN, Huffington Post, The Guardian, The Denver Post, and Fox TV. Cut tree care recommendations, coauthored by with Eric Hinesley at NCSU was also widely disseminated by the National Christmas Tree Association, a number of state Christmas tree organizations, growers, and media sources.

**Websites**

WSU Sudden Oak Death Program (<http://www.puyallup.wsu.edu/ppo/sod/>)

Pacific Madrone Research (<http://www.puyallup.wsu.edu/ppo/madrone/>)

National Elm Trial (<http://www.puyallup.wsu.edu/ppo/elm/>)

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**University of Wisconsin report to NCERA224**

**Dr. Chris Williamson**

1) Emerald Ash Borer – Officially confirmed in 39/72 (54%) of WI counties (essentially the Southern half of WI + Door, Oneida, and Douglas counties). A full list of infested municipalities in Wisconsin can be found here: <http://datcpservices.wisconsin.gov/eab/articleassets/ConfirmedEABFindsInWisconsin.pdf>

2) Magnolia Scale - One of the most commonly reported insect stories on ornamental plants in 2015 (University of Wisconsin-Madison, Insect Diagnostic Laboratory). Magnolia scale was found on a number of different varieties of Magnolias.

3) Viburnum Leaf Beetle - Detected in late summer 2014 in Northern Milwaukee county, recently (2015) found in two Eastern WI counties (Ozaukee and Waukesha).

4) Lily Leaf Beetle – A pest of true lilies; appeared in 2014 in the Wausau area of North-Central WI.  At this point, only Marathon County (Wausau area) appears to have an infestation of this insect and a number of finds in that part of the state were noted in 2015.

5) Japanese Beetle Populations increased to levels of previous years (2007-2013) especially compared to 2014s record low population. Damage throughout the state seemed to be sporadic, and few reports of significant damage surfaced.

6) Gypsy Moth Populations increased in 2015 compared to declining levels over the past several years. Highest populations occurred in three Southern WI counties (Dane, Rock and Walworth).

7) Jumping Worms (formerly referred to as "Asian Crazy worms") Reported in more places in 2015, including some areas on the University of Wisconsin-Madison campus. Most new reports were located in the Southern portion of WI between Madison and Milwaukee.

8) Spotted Wing Drosophila Populations were elevated in 2015, more than 40 WI counties with confirmed SWD populations and increasing.

9) Brown Marmorated Stink Bug: Reports remain low, although they have increased late in 2015. Only a half-dozen reports surfaced early in 2015 (January - March). In October 2015, several new finds started emerging, especially from the Dane County (Madison, WI) area and the Milwaukee area. For the first time in Wisconsin, multiple BMSB adults were being found at the same time. In some cases, 6-8 stink bugs were found invading homes or congregating on the outside of homes.

10) Scale Insects: Elevated reports in 2015. Numerous reports from across the state of honeydew dripping from trees. In most cases, it appeared to be Lecanium scale.

11) Multicolored Asian lady Beetle: Populations have been declining for several years, however an increase was observed in 2014. As of early October, MALB activity seems to be picking up and may be higher than in 2015. Many reports of MALB invading homes and other structures.

12) An "odd ball" that appeared in 2015 is the Picture-winged fly *Ceroxys latiusculus*, it is essentially a "western" version of the cluster fly.  It first appeared at a brewery in Milwaukee, WI---How or why it got there remains a mystery. This is the first record of this species East of the Mississippi River.

**Factsheets and other Publications for 2015**:

[Homeowner Guide to Emerald Ash Borer Treatments” Factsheet. R. C. Williamson and P. J. Liesch. <http://labs.russell.wisc.edu/pddc/files/Fact_Sheets/FC_PDF/Homeowner_Guide_to_EAB_Insecticide_Treatments.pdf>

[Professional Guide to Emerald Ash Borer Treatments Factsheet. R. C. Williamson and P. J. Liesch. <http://labs.russell.wisc.edu/pddc/files/Fact_Sheets/FC_PDF/Professional_Guide_to_EAB_Insecticide_Treatments.pdf>

Iris Borer Factsheet. P. J. Liesch and P. J. Pellitteri. <http://labs.russell.wisc.edu/pddc/files/Fact_Sheets/FC_PDF/Iris_Borer.pdf>

May/June Beetle Factsheet. P. J. Liesch <http://labs.russell.wisc.edu/pddc/files/Fact_Sheets/FC_PDF/MayJune_Beetles.pdf>

Viburnum Leaf Beetle Factsheet. P. J. Liesch. <http://labs.russell.wisc.edu/pddc/files/Fact_Sheets/FC_PDF/Viburnum_Leaf_Beetle.pdf>

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**Oklahoma State University report to NCERA 224**

**Dr. Erik Rebek**

Oklahoma is in the middle of a major outbreak of fall webworm, *Hyphantria cunea*, across the eastern half of the state. We’ve also added several new counties for incidence of crapemyrtle scale infesting landscape plantings of crapemyrtle. See Pest e-Alert articles I’ve provided regarding these two insect pests.

Although emerald ash borer, *Agrilus planipennis*, has not been found in Oklahoma, the Oklahoma Department of Agriculture, Food, and Forestry (ODAFF) is continuing to monitor for this destructive woodboring pest using purple panel traps and tree surveys. The encroachment of emerald ash borer into neighboring Arkansas has Oklahoma state officials and entomologists on high alert. As an extension entomologist, I am active in educating the public about this pest. I have produced Oklahoma Cooperative Extension Publication, L-443: Signs and Symptoms of Emerald Ash Borer, which is useful in identification of the beetle and the damage it causes to ash trees. I am working on two other extension publications that pertain to ash tree identification and look-alike insects that are often confused with emerald ash borer. These publications should be available in late 2015/early 2016.

**First state reports of insects in 2015**

Woodbine borer (*Saperda puncticollis*), April 2015 – found in ODAFF survey trap from Tulsa Co. This pretty beetle attacks and develops in Virginia creeper, grape, and poison ivy.

Sedge aphid (*Thripsaphis ballii*), June 2015 – found on field-collected plants as part of graduate student research project along Deep Fork Creek, Lincoln Co., near Sparks, OK.

Bermudagrass stem maggot (*Atherigona reversura*), August 2015 – found by former graduate student infesting stems of Midland 99 bermudagrass pasture, Pittsburg Co. Adult flies subsequently found in two additional counties in spotted wing drosophila vinegar traps, Payne Co., Tulsa Co.

**Key insect activity in 2015**

Bloodsucking conenose bug (*Triatoma sanguisuga*), July & August 2015 – 2 finds, usually 0 per year.

Bordered patch caterpillars (*Chlosyne lacinia*), June & July 2015 – damage to black-eyed Susan and sunflowers.

Cerambycid woodborers (*Sternidius, Distenia, Neoclytus* spp*.*), June & July 2015 – attacking stressed trees, despite the end of our four-year drought due to heavy rains in spring 2015.

Cicada oviposition damage (various spp.), July & August 2015 – branch and twig dieback observed.

Cotton/melon aphids (*Aphis gossypii*), August 2015 – pest of home gardens.

Cottony maple leaf scale (*Pulvinaria acericola*), June 2015 – found on maple.

Crapemyrtle aphids (*Tinocallis kahawaluokalani*), August 2015 – crapemyrtle leaves, lots of sooty mold reports.

Crapemyrtle scale (*Eriococcus lagerstroemia*), May thru September 2015 – moving north, now found in eight counties in Oklahoma.

Cynipid gall wasps (various spp.), late spring thru fall 2015 – oaks have been particularly hit hard this year.

Elm leaf beetle (*Xanthogaleruca luteola*), May thru September 2015 – more reports than usual.

Euonymus scale (*Unaspis euonymi*), March thru July 2015 – more reports than usual.

Fall armyworm (*Spodoptera frugiperda*), late summer 2015 – pastures; this was a significant pest in home lawns in 2014 but so far, no reports from lawncare specialists in 2015.

Fall webworm (*Hyphantria cunea*), late summer and fall 2015 – extremely heavy damage this year, possibly decade. One report was from Bradford pear!

Forest tent caterpillar (*Malacosoma disstria*), April 2015 – few reports on various trees.

Giant water bug (*Lethocerus* sp.), July thru September 2015 – unusual to get this many reports in a year, most flying to lights. One landed on a person.

Greater peachtree borer (*Synanthedon exitiosa*), June 2015 – peach trunk.

Hackberry nipplegall maker (*Pachypsylla celtidismamma*), April thru July 2015 – many reports of foliar galls.

Kermes scale (*Nanokermes pubescens*?), summer 2015 – oaks.

Morningglory leafminer (*Bedellia somnulentella*), August 2015 – ornamental vine.

Newhouse borer (*Arhopalus productus*), August 2015 – emerging thru sheetrock in new house.

Oak gall midge (*Contarinia* sp.), April 2015 – red oak group.

Oak lecanium scale (*Parthenolecanium quercifex*), January thru May 2015 – oak branches.

Oak woolly aphids (*Stegophylla* sp.), September 2015 – oak leaves in southern part of state.

Periodical cicada (*Magicicada septendecim, M. cassini, M. septendecula*), late May-June 2015 –Brood IV, found all three 17-year cicadas intermixed in this brood.

Pecan leaf phylloxera (*Phylloxera notabilis*), June thru August 2015 – pecan leaves.

Salvinia stem-borer moth caterpillars (*Samea multiplicalis*), May 2015 – found by ODAFF on water lettuce.

Spotted wing drosophila (*Drosophila suzukii*), June-September 2015 – blackberry, grape, and forest trees.

Sugarcane aphid (*Melanaphis sacchari*), summer 2015 – sorghum.

Sunflower moth (*Homoeosoma ellectellum*), August 2015 – commercial sunflower fields.

Vein pocket gall (*Macrodiplosis quercusoruca*), summer 2015 – red oak group, heavier than normal reports this year.

Walnut caterpillar (*Datana* *integerrima*), summer 2015 – walnut, pecan, heavier than normal reports this year.

Wheel bug (*Arilus* *cristatus*), in this case lack thereof – no reports this year!

Woolly apple aphid (*Eriosoma lanigerum*), August 2015 – apple and Pyracantha.

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**Clemson University report to NCERA 224**

**Dr. JC Chong**

***Objective 1****: New and emerging pests: Investigate detection methods, biology, and management of new and emerging pests*

Study 1. Species diversity and seasonal activity of native and exotic bark and ambrosia beetles in three habitats

A study was initiated in 2011 and has been completed in 2014. This study determines the species diversity and seasonal activity of the native and exotic bark and ambrosia beetles in ornamental plant nurseries, native forests, and botanical gardens in South Carolina. A total of 82 bark and ambrosia beetle species, as well as 26 roundheaded borer species, 8 flatheaded borer species and 4 wood wasp species, were detected in the three habitats. Adult seasonal activity was also determined for these species and will be used in developing borer management programs in various habitats.

Study 2. Life history and natural enemy associates of the oak lecanium scale

A study on the life history and natural enemy assemblage of the oak lecnaium scale has been completed in 2015. The oak lecanium scale is a soft scale species that attack oak trees planted in urban landscape. A degree-day model was developed to better predict the crawler emergence timing. This project also documented 21 parasitoid species and 12 predator species of the lecanium scale, which caused up to 85% reduction in scale insect populations.

***Objective 2****: Pesticide technology development: Evaluate effectiveness of reduced–risk pesticides, biopesticides, new and novel chemistries, and application technologies for control of key disease and arthropod pests of landscapes, nurseries, and Christmas trees*

Study 3: Efficacy of cyflumetofen (Sultan) and adjuvant combination against twospotted spider mite in outdoor ornamentals production

Collaborator: Kathie Kalmowitz (BASF)

Cyflumetofen is a miticide of beta-ketonitrile derivative that inhibits mitochondrial complex II electron transport chain (IRAC MOA # 25). The chemistry was recently introduced as Sultan into the ornamentals market by BASF for the management of spider mites (Tetranychidae). A study was conducted to investigate the efficacy of cyflumetofen, when applied in combination with one of five adjuvants (Southern Ag Spreader-Sticker, Winfield AirCover, Herrell’s SprayMax, Helena’s Dyne-Amic and Helena’s Induce) and at two application volumes (50 and 100 gallons/acre), against twospotted spider mite feeding on butterfly bushes in outdoor nursery production. The study suggested that cyflumetofen was extremely effective in reducing spider mite abundance and damage, regardless of the adjuvant used or the application volume.

***Objective 3****: Pesticide alternatives: develop management strategies for key pests based on classical biological control, host plant resistance and cultural control*

Study 4: Field acute and residual toxicity of cyflumetofen against the predatory mites

Collaborators: James Bethke (University of California Cooperative Extension), Kathie Kalmowitz (BASF), Lance Osborne (University of Florida – Apopka)

This study was initiated in 2013 and is repeated in 2014 and 2015. The same experimental protocol was developed and implemented by collaborators at three locations in the country to investigate the residual and acute toxicity of cyflumetofen against two of the most frequently used predatory mite species (*Phytoseiulus persimilis* and *Amblyseius swirskii*). The acute toxicity was tested by treating plants with the two predatory mite species 1 day after the release. Toxicity of 1-, 3-, 7- and 14-day residue was also tested by releasing the predatory mites on treated plants at the prescribed intervals. Cyflumetofen applied at 6.5 and 13 fl oz/100 gallons appeared to be compatible with both *P. persimilis* and *A. swirskii* where survival rates of the predatory mites on treated plants were similar to those on the water-treated plants. Future studies will be conducted to determine the effects of the chemistry on predatory reproduction.

***Objective 4****: Technology transfer: Develop and deliver science-based educational materials focused on management of key pests through outlets such as mass media, publications and fact sheets, eXtension.org and social media*

Study 5: Development of a handbook of wood boring insects of ornamental trees and shrubs of the eastern US

Collaborators: Karla Addesso (Tennessee State University), Joshua Basham (Tenessee State University), Alicia Bray (Central Connecticut State University), Emily Dobbs (University of Kentucky), Steven Frank (North Carolina State University), Dan Gilrein (Cornell University Cooperative Extension), Matt Ginzel (Purdue University), Frank Hale (University of Tennessee), Dan Herms (Ohio State University), Bill Klingeman (University of Tennessee), Joseph Lampley (Tennessee State University), Jonathan Larson (University of Kentucky), Deb McCullough (Michigan State University), Venessa Muilenbeurg (Ohio State University), Jason Oliver (Tennessee State University), Randy Ploetz (University of Florida), Dan Potter (University of Kentucky), Christopher Ranger (USDA-ARS), Laurie Reid (SC Forestry Commission), Sarah Vanek (University of Kentucky), Andrew Young (University of Tennessee), Nadeer Youssef (Tennessee State University)

A handbook that will assist growers, landscape care professionals, arborists, ground managers and extension personnel in diagnose, identify, monitor and manage common wood boring insects of ornamental trees and shrubs in the eastern United States is being prepared. About 45 most commonly encountered species and various chapters on IPM, monitoring, pheromone and kairomone communications, disease and invasive species are included in the handbook. Currently, 29 out of the 46 chapters have been prepared. The project was initiated in 2012 and will continue until the handbook is completed and published. The Entomological Society of America has approved the handbook to be published as part of the ESA Handbook series in 2016.

**OUTCOMES/IMPACTS:**

Bark and ambrosia beetles are important pests of ornamental plant and silvicultural productions, as well as in urban forestry. In ornamental plant nursery of South Carolina, damage by the granulate ambrosia beetle can reach as high as 13% of susceptible tree species stocks in some years. Management of the ambrosia beetle relies on well-timed applications of pyrethroid insecticides. Current management recommendation includes monitoring the spring adult flight using an ethanol trap, and weekly or biweekly applications of bifenthrin or permethrin to the trunk of the susceptible trees as soon as adult beetles are captured in the ethanol trap. Preventive application timed to the adult flight in the spring can reduce the damage to 1%. Applications of systemic insecticides have not been effective in numerous trials. A better understand of the species richness and seasonal activity of bark and ambrosia beetle can inform ornamental tree growers, foresters, plant managers and landscape care professionals on potential pest species in the local and the best timing for preventive application of insecticides.

The lecanium scales, *Parthenolecanium* spp., are the most common pest species of oak trees grown in the urban landscapes of the southern US. The project has identified the timing of the peak crawler emergence for all four states. Based on the results of this project, a degree-day model and a plant phenological indicator model had also been developed. The stakeholders can use the information on crawler emergence, degree-day model and plant phenological indicator model to accurately time the application of insecticides to achieve the greatest efficacy and limit exposure of insecticides to the environment and non-target organisms. Information on the assemblage, activity period and impact of natural enemies suggested that practices that conserve natural enemies, such as judicious use of non-compatible insecticides, can be combined with chemical control tactics to achieve greater efficacy in scale insect population management.

Cyflumetofen is registered for the management of spider mite species in indoor and outdoor ornamental plant production and maintenance. Question remains on whether the inclusion of an adjuvant is needed to increase the efficacy of cyflumetofen in outdoor production, and, if so, which adjuvant may be the most suitable. A study conducted during this period showed that the addition of an adjuvant may not be needed, even when cyflumetofen is applied at a lower than label-recommended application volume. This study generated information that would allow growers to use the product more effectively.

Cyflumetofen is a compatible chemical for the predatory mites *P. persimilis* and *A. swirskii* in a multi-state project. The results suggested cyflumetofen could be used without significant negative impact on *A. swirskii* and *P. persimilis* when these predatory mites are used in biological control programs against whiteflies, thrips and twospotted spider mite in greenhouses and nurseries. Therefore, cyflumetofen can be safely incorporated into a comprehensive, multiple-target IPM system in ornamental plant production systems.

The handbook on wood boring insects of ornamental trees and shrubs of the eastern US is expected to become an important reference for producers and managers of ornamental plants, as well as extension personnel. There are few, if any, comparable source of information or publication, particularly considering the inclusion of many useful and informative photographs.

**PUBLICATIONS:**

Extension:

Chong, J.-H. 2015. False oleander scale, *Pseudaulacaspis cockerelli* (a.k.a. magnolia white scale). The South Carolina Nurseryman. May/June 2015, pp. X-Y.

Chong, J.-H. 2015. Wax myrtle scale, *Melanaspis deklei*. The South Carolina Nurseryman. January/February 2015, pp. 32-33.

Chong, J.-H. 2014. New insecticides for the turf market. South Carolina Sod Producers Association Newsletter. December 2014.

Robayo Camacho, E., and J.-H. Chong. 2014. Florida wax scale, *Ceroplastes floridensis*. The South Carolina Nurseryman. November/December 2014, 18-19.

Chong, J.-H. 2014. Brother, can you spare a fall armyworm? South Carolina Sod Producers Association Newsletter. October 2014.

Chong, J.-H. 2014. Scale insects: The banes of ornamentals. The South Carolina Nurseryman. September/October 2014, pp. 26-28.

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**University of Delaware report to NCERA 224**

**Dr. Brian Kunkel**

Chemical ways to treat red headed flea beetle in ornamental greenhouses and nurseries in ppt

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**University of Minnesota report to NCERA224**

**Dr. Vera Krischik**

The conservation of beneficial insects, that includes bees, insect predators, parasitic wasps, and butterflies, is an essential part of Integrated Pest management (IPM) programs. IPM promotes multiple tactics to manage pests and to suppress the population size below levels that will damage the plant. IPM tactics include cultural control, sanitation, biological control, using insecticides friendly to beneficial insects, and finally the use of conventional insecticides. IPM recognizes that the few remaining pest insects will support beneficial predators and parasitic wasps. When scouting plants for pest insects, check for populations of both pest and beneficial insects, such as lady beetles and bees. If beneficial insects are present, wait to spray insecticides to see if the beneficial insects control the pest insects or use specific insecticides that only target the pest insect. Do not apply insecticides while plants are in full bloom. If possible avoid beneficial insects by spraying leaves in the evening when bees and lady beetles are not foraging.

Neonicotinoid systemic insecticides have been implicated in the decline of bees and other beneficial insects. The European Union banned the use of neonicotinoid insecticides from 2014-2016 on crops and plants that bee’s visit. The concern was the residue in pollen and nectar and their negative effects on survival and foraging behavior of bees.

There are few systemic insecticides, while there are many systemic herbicides and fungicides. Systemic, neonicotinoid insecticides are the most widely used insecticides in the world, due to their low mammalian toxicity and the ability of the insecticide to move systemically from soil into the entire plant, including pollen and nectar. Application methods include seed treatments, foliar sprays, soil and trunk drenches, and trunk-injections. Flowers that open after being sprayed with contact insecticides do not contain insecticide residue, while toxicity to pests lasts for 1-3 weeks. However, flowers that open after systemic insecticides are sprayed can contain the insecticide residue for many months in both the leaves and pollen and nectar.

There are six neonicotinoid active ingredients, imidacloprid, dinotefuran, thiamethoxam, and clothianidin, of which acetamiprid and thiacloprid are the least toxic to bees. There is another systemic insecticide, fipronil that is used around structures that is also toxic to bees. You will find these active ingredients listed on the insecticide label in small print. The neonicotinoid class of insecticides is highly toxic to bees and kills bees at around 180 ppb in flower nectar or pollen. However, sublethal doses of neonicotinoid insecticide starting around 10 ppb, causes bees to lose navigation and foraging skills. The longevity and amount of the neonicotinoid in the pollen and nectar will depend on application method, concentration applied, and binding capacity of the soil. More research is needed to determine residual levels from different applications.

The use of neonicotinoid insecticides as trunk injections and soil drenches for ash trees is important to slow the spread of the exotic, invasive Emerald Ash Borer and other invasive pests. As bees do not collect ash pollen in quantities, the risk to bee pollinators is low. In contrast, the use of neonicotinoid insecticides on flowering garden plants, shrubs and trees, including linden and basswood trees can kill bees and beneficial insects that utilize the flowers for pollen and nectar. It is wise to avoid using systemic neonicotinoid insecticides on flowering plants that bees visit regularly. Instead use spot treatments of contact insecticides.

**New EPA labeling for neonicotinoid insecticides as of March 2014**

**APPLICATION RESTRICTIONS EXIST FOR THIS PRODUCT BECAUSE OF RISK TO BEES AND OTHER INSECT POLLINATORS. FOLLOW APPLICATION RESTRICTIONS FOUND IN THE DIRECTIONS FOR USE TO PROTECT POLLINATORS**

****

The new EPA bee hazard icon in the directions for use on insecticide labels

EPA has added new language to neonicotinoid insecticide products (imidacloprid, dinotefuran, thiamethoxam, and clothianidin) to protect bees and other insect pollinators. The bee icon above signals that the pesticide has potential to harm bees. The language in the new bee advisory box explains application restrictions to protect bees.

**Bee and other insect pollinators can be exposed to the product from:**

1. Direct contact during foliar application or contact with residues on plant surfaces after foliar application. 2. Ingestion of residues in nectar and pollen when the pesticide is applied as a seed treatment, soil, tree injection, as well as foliar application.

**When using this product take steps to:**

1. Minimize exposure when bees are foraging on pollinator attractive plants around the application site. 2. Minimize drift of this product onto beehives or to off-site pollinator attractive habitat. Drift of this product onto beehives can result in bee kills.

Bee kills should be reported to Minnesota Department of Agriculture (www.mda.state.mn.us , type bee kill into search), National Pesticide Information Center (www.ipm.orst.edu), and the EPA (beekill@epa.gov).

**Nursery and greenhouse growers have alternatives to systemic insecticides.**

The EPA has been registering selective, insecticides that conserve beneficial insects and pollinators.

S-kinoprene (Enstar II), juvenile hormone mimic

Miticides (Akari, Hexygon)

Chlorantraniliprole (Acelepryn), grubs in soil or most landscape pests

**New Minnesota Bee Labeling Laws July 1 2014**

The following list of potential systemic insecticides affected by the law, the use of which (depending on their product labels) may render the labelling of plants as non-compliant with the law if residues are detected in the plant material, include:

On the list, but not registered for use on nursery, greenhouse, and landscape by the EPA (24 insecticides) are: aldicarb, bendiocarb, demeton-s-methyl, ethoprop, dichlorvos, dicrotophos (cotton only), fensulfothion (field crops), fenthiom (mosquitoes in Florida), fipronil, methamidophos, methomyl, methyl bromide, mevinphos, oxydemeton-methyl phosphamidon, sulfoxaflor, terbufos, tralomethrin (roach), carbofuran (U.S. cancelled), dimethoate (U.S. cancelled), disulfoton (U.S. cancelled), mexacarbate (U.S. cancelled), phorate (U.S. cancelled), ronnel (U.S. cancelled).

Here is the list of systemic insecticides identified by the law as not approved on bee-friendly-labeled plants. These insecticides are registered for use on nursery, greenhouse, and landscape by the EPA (18 insecticides): abamectin, acephate, acetamiprid, avermectin, bifenazate, carbaryl, chlorfenapyr, clothianidin, cyantraniliprole, dinotefuran, emamectin benzoate, imidacloprid, milbemectin, oxamyl, pymetrozine, spinosad, thiacloprid, thiamethoxam.

|  |
| --- |
| **Toxicity to Pollinators of Insecticides Used in Greenhouse, Nursery, and Landscapes****Vera Krischik Dept Entomology, Uminnesota,** **krisc001@umn.edu****, 612.625.7044,** **updated August 4 2015** |
| In gray are insecticides not permitted by the MDA on bee-friendly-labeled plants. Systemic neonicotinoid insecticides (imidacloprid, clothianidin, dinotefuran, and thiamethoxam) are translocated to pollen and nectar for some time after application. Contact insecticides should not be translocated to pollen and nectar and should not be present in new flowers. Many contact insecticides are toxic to bees and should not be sprayed directly on foraging bees or flowers. In greenhouse structures if you use contact insecticides during cultivation; the residue should be minimal after 5 weeks.  |
| **Chemical class**  | **Common name** | **Examples of trade names** | **LD 50\*** | **Toxicity to honeybees\*\*** |
| **ug/bee** | **Non** | **Mod****Toxic** | **Highly** |
| Carbamates | carbarylmethomyl | Sevin, Lannate | 0.0140.816 |  |  | xx |
| Neonicotinoids | imidacloprid (I) thiamethoxam (T)clothianidin (C) dinotefuran (D) imid+bifenthrin (I,B) | Merit, MarathonFlagship, MeridianArena, AloftSafariAllectusField cropsGaucho (I), Poncho (C), Cruiser(T) (seed treatments), Admire/Provado (I)Venom (C),Platinum (T) | 0.0040.0040.0050.023 |  |  | xxxx |
| less toxic: acetamiprid thiacloprid | Tristar (A), Assail (A) Calypso (T) | 14.527.8 | xx |  |  |
| Organophosphates | acephate chlorpyrifos dimethoatemalathion phosmet | Orthene Dursban/Lorsban Dimethoate Malathion Imidan | 0.1082 0.060.0380.160. 1 |  |  | xxxxx |
| Pyrethroids | bifenthrin cyfluthrin, fenpropathrin lambda-cyhalothrinpermethrinresmethrin | Attain/TalstarTempo, DecathalonTame,ScimitarAstro, Pouncefoggers  | 0.10.001 0.050.0380.0290.065 |  |  | xxxxx |
| Botanical | pyrethrin | Pyganic | 0.15 |  |  | x |
| Insect growth regulators | diflubenzurontebufenozide | Adept, DimilinConfirm | 25234 | xx |  |  |
| azadirachtinbuprofezin pyriproxyfen | AzaDirect, AzatinTalusDistance | 2.5163100 | xx | x |  |
| novaluron | Pedestal | 150 | x |  |  |
| cyromazine | Citation | 25 | x |  |  |
| Juvenile hormone  | s-kinoprene | Enstar II | 35 | x |  |  |
| Anthranilic Diamides | chlorantraniliprolecyantraniliprole | Acelepryn Mainspring | >1040.116 | x |  | x |
| Macrocyclic lactones | abamectinavermectinemamectinbenzoate | AvidSiroccoTree-age, Enfold | 0.009 0.410.285 |  |  | xxx |
| Miticides | acequinocyl extoxazole fenpyroximate fenbutatin-oxidehalofenozide | ShuttleTetraSan, BeethovenAkari,VendexMach II | >1002001623982100 | xxxxx |  |  |
| clofentezine, hexythiazox | OvationHexygon | 111200 | xx |  |  |
| bifenazate | Floramite, Sirocco | 7.8 |  | x |  |
| pyridaben | Sanmite | 0.024 |  |  | x |
| chlorfenapyr  | Pylon | 0.12 |  |  | x |
| Spinosyns | spinosad, less toxic when dry | Conserve/Entrust less toxic dried | 0.05 |  |  | x |
| Tetronic acids | spirotetramat spiromesifen | Kontos Judo, Forbid | 107200 | x x |  |  |
| GABA-channel  | fipronil | Fipronil, Termidor | 0.004 |  |  | x |
| Pyridine carboxamide | flonicamid | Aria | 60.5 | x |  |  |
| Pyridine azomethines | pymetrozine | Endeavor | 158.5 | x |  |  |
| Other insecticides | *Bacillus thuringiensis* | Bt/Dipel  | na | x |  |  |
| potassium salts fatty acids soaps | Surround, M-Pede |  | x |  |  |
| horticultural mineral oils  | Monterey Oil |  |  | x |  |
| *The information given herein is supplied with the understanding that no discrimination is intended and no endorsement by the University of Minnesota Extension. Remember, the label is law.* |
| \*\*Toxicity Category I, highly toxic to bees, Acute Contact LD50 is < 2 μg/beeToxicity Category II, moderately toxic to bees, the LD50 is 2-10.99 μg/bee Toxicity Category III, Relatively nontoxic, NT, to bees, the LD50 is 11-100 μg/bee\*1. Protecting honeybees from pesticides, Purdue Extension, E-53W, Krupke, C., G. Hunt, and R. Foster, June 2014, <http://extension.entm.purdue.edu/publications/E-53.pdf> 2.How to reduce bee poisoning from pesticides, A Pacific Northwest Extension Publication, OSU, UI, WSU, PNW 591, Hooven, L., Sagili, and E. Johansen; Pesticide toxicity to bees, <http://pesticidestewardship.org/PollinatorProtection/Documents/How%20to%20Reduce%20Bee%20Poisoning%20from%20Pesticides_PNW.pdf>3. Pesticide stewardship, <http://pesticidestewardship.org/PollinatorProtection/Pages/Pesticide-Toxicity-to-Bees.aspx>4. Farmland birds, list of EPA 2011 pesticides and LD50, <http://www.farmlandbirds.net/content/acute-toxicity-ld50-values-honey-bees-all-pesticides-fungicides-herbicides-insecticides-etc-> 5. University of Hertfordshire PPDB, pesticide properties database, <http://sitem.herts.ac.uk/aeru/ppdb/en/index.htm> 6. Pesticide Target Interaction Base, <http://lilab.ecust.edu.cn/ptid/>7.Safety and use of neonicotinoids insecticides in turfgrass, Doug Richmond, Purdue University<http://extension.entm.purdue.edu/neonicotinoids/PDF/Safetyanduseofneonicotinoidsinturfgrass.pdf> |

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**Ohio report to NCERA 224**

**Dr. Heping Zhu, USDA/ARS, ATRU, Wooster, OH**

**Mr. Randall Zondag, The Ohio State University Extension, Lake County, OH 44077**

**Integration of Application Technologies into IPM Programs to Reduce Use of Pesticides for Effective Controls of Arthropod Pests and Plant Diseases**

Current label recommendations of pesticides for arthropod pests and plant diseases in the nursery and green industry are vague and frequently result in excessive pesticide use. The objective of this research was to demonstrate that modifications of spray application techniques with current spray equipment in ornamental nursery production could reduce pesticide use. The efficacy of half rates and full rates of both active ingredients and carrier was investigated in commercial nurseries with air-assisted sprayers in two tests and a State inspector survey for the control of arthropod pests and plant diseases. Sprayers were optimized with properly sized nozzles and properly calibrated operating parameters. In Test 1, treatments were conducted in approximately 0.5 ha plot each in three commercial nurseries for control of arthropod pests and diseases, and in Test 2, the same treatment for aphid control was evaluated in a Birch tree plot. The survey was a compilation of the pests and diseases that were diagnosed by State inspectors in over 2,800 plant varieties and species from two commercial nursery fields (total about 280 hectares) after the spray treatments in six growing seasons. Crop damage by 49 insects and 40 diseases were surveyed for different application rates. The studies revealed that insect and disease control using 50% of the label rates was as effective as full rates when quality spray coverage on targets was achieved, resulting in real cost benefits to producers, consumer

**Integration of New Laser-guided Spray Technology into IPM Programs for Efficacious Insect and Disease Control**

Current application technology for floral, nursery, and tree fruit crops requires excessive amounts of sprays to control pests due to a great diversity in canopy structure and leaf density. Critical innovative technology is needed to increase application efficiency and reduce uncertainties for conventional pesticide sprayers to achieve real cost benefits with new pesticide application strategies for these specialty crop producers, consumers and the environment.

An automated variable-rate, air-assisted precision sprayer was developed to minimize human involvement in spray applications. The automatically-processed spraying system (fig. 1) is able to characterize the presence, size, shape, and foliage density of target trees and accommodate sprayer travel speed to apply appropriate variable amounts of pesticides based on tree canopy needs in real time. It integrates a high-speed, 270° radial and 30-m range laser scanning sensor in conjunction with a non-contact Doppler radar travel speed sensor, a sophisticated automatic nozzle flow rate controller, an embedded computer, a touch screen, a manual switch box, and 40 pulse-width-modulated variable-rate nozzles on a multi-port air-assisted delivery system.

Automatically-controlled spray capabilities to the sprayer are achieved by the sensors and the embedded computer. The laser scanning sensor, which is mounted between the tractor and sprayer, detects the return distance signals of the bilateral tree structure. An algorithm, written in C++ language, translates these signals along with the sprayer travel speed into tree surface structures and determines the amount of sprays for each nozzle. All 40 nozzles on two sides of the sprayer can independently discharge variable flow rates to their designated canopy sections. The embedded computer, touch screen and switch box operational components are mounted in the tractor cab. The functional touch screen displays the sprayer travel speed, total discharged spray volume, spray width, and active nozzles. The operators can also modify spray parameters through the touch screen as needed

2015 Ohio Report report to NCERA 224

Pierluigi (Enrico) Bonello

Department of Plant Pathology

The Ohio State University

Columbus, OH 43214

bonello.2@osu.edu

**Project:** **NCERA224: IPM Strategies for Arthropod Pests and Diseases in Nurseries and Landscapes**

**Ohio Report for the Period**: 10/1/14 – 9/30/2015

**OUTPUTS / ACCOMPLISHMENTS:**

*Obj. 3: Pesticide alternatives: Develop management strategies for key pests based on classical biological control (i.e., predators and parasitoids), host plant resistance, and cultural control.*

1. **Resistance mechanisms in the Austrian pine / *Diplodia pinea*** **pathosystem**. Collaborators: Patrick Sherwood (Ph.D. student), Dan Herms (Dept. of Entomology), Don Cipollini (Dept. of Biological Sciences, Wright State University).

Plants experiencing drought stress are frequently more susceptible to pathogens, likely via alterations in physiology that create favorable conditions for pathogens. Common plant responses to drought include the production of reactive oxygen species (ROS) and the accumulation of free amino acids, particularly proline. These same phenomena also frequently occur during pathogenic attack. Therefore, drought-induced perturbations in amino acid and ROS metabolism could potentially contribute to the observed enhanced susceptibility. Furthermore, N availability can influence amino acid accumulation and affect plant resistance, but its contributions to drought-induced susceptibility is largely unexplored. Here we show that drought induces accumulation of hydrogen peroxide (H2O2) in Austrian pine (*Pinus nigra* Arnold) shoots, but that shoot infection by the blight and canker pathogen *Diplodia sapinea* (Fr.) Fuckel leads to large reductions in H2O2 levels in droughted plants. In in vitro assays, H2O2 was toxic to *D. sapinea*, and the fungus responded to this oxidative stress by increasing catalase and peroxidase activities, resulting in substantial H2O2 degradation. Proline increased in response to drought and infection when examined independently, but unlike all other amino acids, proline further increased in infected shoots of droughted trees. In the same tissues, the proline precursor, glutamate, decreased significantly. Proline was found to protect *D. sapinea* from H2O2 damage, while also serving as a preferred N source in vitro. Fertilization increased constitutive and drought-induced levels of some amino acids, but did not affect plant resistance. A new model integrating interactions of proline and H2O2 metabolism with drought and fungal infection of plants is proposed.

1. **Chemistry of coast live oak defense response to *P. ramorum***. Collaborators: Anna Conrad (Ph.D. student), Brice McPherson and David Wood (Dept. of Environental Science, Policy, and Management, UC Berkeley).

Over the last two decades coast live oak (CLO) dominance in many California coastal ecosystems has been threatened by the alien invasive pathogen *Phytophthora ramorum*, the causal agent of sudden oak death. In spite of high infection and mortality rates in some areas, the presence of apparently resistant trees has been observed, including trees that become infected but recover over time. However, identifying resistant trees based on recovery alone can take many years. The objective of this study was to determine if Fourier-transform infrared (FT-IR) spectroscopy, a chemical fingerprinting technique, can be used to identify CLO resistant to *P. ramorum* prior to infection. Soft independent modeling of class analogy identified spectral regions that differed between resistant and susceptible trees. Regions most useful for discrimination were associated with carbonyl group vibrations. Additionally, concentrations of two putative phenolic biomarkers of resistance were predicted using partial least squares regression; > 99% of the variation was explained by this analysis. This study demonstrates that chemical fingerprinting can be used to identify resistance in a natural population of forest trees prior to infection with a pathogen. FT-IR spectroscopy may be a useful approach for managing forests impacted by sudden oak death, as well as in other situations where emerging or existing forest pests and diseases are of concern.

1. **Molecular biology of ash resistance to EAB**. Collaborators: David Showalter (Ph.D. student), Caterina Villari (post-doc), Amy Hill (technician), Dan Herms (Dept. of Entomology), Don Cipollini (Dept. of Biological Sciences, Wright State University).

We reviewed literature on host resistance of ash to emerald ash borer (EAB, *Agrilus planipennis*), an invasive species causing widespread mortality of ash. Manchurian ash (*Fraxinus mandshurica*), which coevolved with EAB, is more resistant than evolutionarily naïve North American and European congeners. Manchurian ash was less preferred for adult feeding and oviposition than susceptible hosts, more resistant to larval feeding, and had higher constitutive concentrations of bark lignans, coumarins, proline, tyramine, defensive proteins, and was characterized by faster oxidation of phenolics. Consistent with EAB being a secondary colonizer of coevolved hosts, drought stress decreased resistance of Manchurian ash, but had no effect on constitutive bark phenolics, suggesting they do not contribute to increased susceptibility in response to drought stress. Induced resistance of North American species to EAB in response to exogenous application of methyl jasmonate was associated with increased bark concentrations of verbascoside, lignin and/or trypsin inhibitors, which decreased larval survival and/or growth in bioassays. This suggests that these inherently susceptible species possess latent defenses that are not induced naturally by larval colonization, perhaps because they fail to recognize larval cues or respond quickly enough. Finally, we propose future research directions that would address some critical knowledge gaps.

**OUTCOMES / IMPACTS:**

*Obj. 3: Pesticide alternatives: Develop management strategies for key pests based on classical biological control (i.e., predators and parasitoids), host plant resistance, and cultural control.*

Knowing which metabolic pathways are significant in pine interaction with *D. pinea* and how droght stress actually is linked to increased susceptility to the same pathogen will allow for a more rational approach to the management of this and similar diseases.

Non-adaptation/maladaptation of north American ash to EAB is reflected in differential expression of several constitutive and inducible resistance traits relative to Manchurian ash. Such maladaptation may be further exacerbated by environmental conditions that favor susceptibility. For example, global warming will likely lead to more frequent and intense, extreme weather events, including prolonged droughts and excessive precipitation. It is expected that these weather extremes will negatively impact trees both directly and indirectly, via reduced resistance to pests, including wood boring beetles such as EAB. Finding that some compounds identified in ash as potential biomarkers of resistance to EAB are not affected by water availability will allow us to focus on different traits that are instead affected by, for example, drought.

Understanding the phenotype that characterizes CLO resistant to *P. ramorum*, both at the whole plant and at the chemical levels, will allow for a rational approach to the identification and protection of resistant genotypes ahead of the infection front.

My program has trained 3 PhD students (Anna Conrad, Patrick Sherwood, and David Showalter), 1 undergraduate intern (Brian Smith) and 1 post-doc (Caterina Villari).

**PUBLICATIONS: (5)**

* Villari C, Herms DA, Whitehill JGA, Cipollini DF, **Bonello P** (2015). Progress and gaps in understanding mechanisms of ash resistance to emerald ash borer, a model for wood boring insects that kill angiosperm trees. (Invited Tansley Review.) New Phytologist - DOI:10.1111/nph.13604.
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3. Conrad, A.O., L. Rodriguez-Saona, B.A. McPherson, D.L. Wood, and **P. Bonello**. 2015. Constitutive phenolic biomarkers identify *Quercus agrifolia* (coast live oak) resistant to the invasive pathogen *Phytophthora ramorum*. Genetics of Tree-Parasite Interactions, Orleans, France, Aug. 23-28.
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5. Sherwood, P., C. Villari, P. Capretti, and **P. Bonello**. 2015. Abiotic stress and mechanisms of induced tree susceptibility to fungal pathogens. IUFRO Tree Biotechnology Conference 2015, Florence, Italy, June 8-12.
6. Michelozzi, M., Pepori, A.L., Calamai, L., Cencetti, G., Santini, A., **Bonello, P.**, and L. Luchi. 2015. The impact of North American root-rot disease fungus *Heterobasidion irregulare* on ecophysiological properties, volatile terpenoids and transcripts of *Pinus.* IUFRO Tree Biotechnology Conference 2015, Florence, Italy, June 8-12.
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18. Villari C., Chakraborty S., Rigsby C., Cipollini F.D., Herms D.A., Bonello P., 2014. Potential role of alkaloids and monoamines in ash resistance to emerald ash borer. 24th IUFRO World Congress, Salt Lake City, UT, Oct. 5-11.
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