**WERA-060: Resistance**
**Arizona: Annual Resistance Status Report**
**January 6, 2012**

Peter C. Ellsworth, Al Fournier, Bruce Tabashnik, Xianchun Li, John Palumbo
Arizona Pest Management Center & Department of Entomology
& William B. McCloskey, School of Plant Sciences, University of Arizona

## Stabilizing Cross-commodity Whitefly Management and Completing Transition to Novel Reduced Risk Chemistries

This project was funded through a Pest Management Alternatives Program (PMAP) grant (Li, Palumbo, Ellsworth & Fournier), heavily leveraged through other resources (Arizona Cotton Growers Association, Cotton Incorporated and industry support). The project includes evaluation of baseline susceptibility and resistance risk to whiteflies for new novel chemistries, including cross-resistance potential with current management tools. We are also evaluating and comparing field efficacy, non-target effects and economic effectiveness of the new chemistries with standards in cotton, melon and vegetable crops against whiteflies. Based on this research we are in the process of developing a new, sustainable stakeholder-driven cross-commodity whitefly management program and will transfer this technology to growers and PCAs through a comprehensive outreach plan incorporating field demonstrations, print and online publications, face-to-face trainings and peer network dissemination. We are in the third year of this two-year project.

Update: Assays of field-collected whiteflies conducted in Li's lab have shown a significant drop in mortality rates for acetamiprid-treated whiteflies over the past two years, ca. 60% median mortality in 2010 versus just 30% in 2011. Dr. Peter Ellsworth solicited feedback from pest control advisors at Extension meetings in late 2011 on their observations of field performance of acetamiprid, and got mixed responses, but most agreed that it isn't working as well as when it was introduced. Since 2005, performance for imidacloprid against whiteflies on vegetables has also declined, based on data from Dr. John Palumbo. We have examined the use patterns of available AIs across crops and have developed a draft concept that will be put up for discussion with industry reps and PCAs at an upcoming meeting.

***Impact:*** *The anticipated impact is promotion of statewide adoption of cross-commodity pesticide use practices that will help sustain important chemical tools for whitefly management across key crops in Arizona.*

## Statewide Whitefly (*Bemisia tabaci*) Resistance Monitoring Program

Statewide monitoring of whitefly resistance to pyriproxyfen, buprofezin, neonicotinoids, spiromesifen and synergized pyrethroids has been conducted in Arizona for over a decade. Work previously done in Dr. Tim Dennehy's lab is now being carried on by Dr. Xianchun Li's lab.

**Findings:** Field populations of B biotype whitefly are still susceptible to buprofezin and spiromesifen, but have developed moderate levels of resistance to pyriproxyfen and synergised pyrethroids for several years. Both cytochrome P450 monooxygenases (P450) and glutathione S-transferases (GST) are involved in whitefly resistance to pyriproxyfen. In 2011, field populations of B biotype whitefly have also developed low to medium levels of resistance to neonicotinoids tested (imidacloprid and acetamiprid). Consistent with our lab bioassay results, complaints on the field efficacy of neonicotinoids have increased this year. Lab bioassays also show that such field-evolved neonicotinoid resistance decrease significantly after 2-3 generations' lab rearing without exposure to neonicotinoids. Synergism experiments suggest that cytochrome P450 monooxygenases (P450) are involved in field-evolved neonicotinoid resistance. All these resistant populations are susceptible to novel chemistries including rynaxypyr, cyazypyr, spirotetramat, and pyrifluquinazon, based on current research. We have established the baseline susceptibilities of B biotype whiteflies to these novel insecticides.

We have surveyed the distribution of Q biotype whiteflies in Arizona, a biotype of worldwide significance and often with severe resistances to a wide array of chemistry. As of this year, Q biotype whiteflies in AZ are still limited to greenhouse plants and ornamentals. We have detected two subclades of Q biotype, designated as Q1 and Q2, respectively. We have developed a PCR-RFLP technique to differentiate Q1, Q2, and B biotype whiteflies. We have also monitored the resistance of Q biotype whitefly populations collected from ornamentals. All Q populations we have tested are resistant to the insecticides currently used for control of the B biotype whiteflies. All of the Q populations we have tested so far are susceptible to cyazypyr and rynaxypyr. But we have 1-2 Q populations that are resistant to the other two novel insecticides, namely, spirotetramat and pyrifluquinazon.

**Large-Scale, Spatially-Explicit Test of the Refuge Strategy for Delaying Insecticide Resistance**

Work in this area was published in PNAS this year:
Carrière, Y., Ellers-Kirk, C., Harthfield, K., Larocque, G., Degain, B., Dutilleul, P., Dennehy, T.J., Marsh, S.E., Crowder, D.W., Li, X., Ellsworth, P.C., Naranjo, S.E., Palumbo, J.C., Fournier, A., Antilla, L., Tabashnik, B.E. 2011. Large-Scale, Spatially-Explicit Test of the Refuge Strategy for Delaying Insecticide Resistance. Proceedings of the National Academy of Sciences DOI: 10.1073. http://www.pnas.org/cgi/doi/10.1073/pnas.1117851109

**Abstract:** The refuge strategy is used worldwide to delay the evolution of pest resistance to insecticides that are either sprayed or produced by transgenic *Bacillus thuringiensis* (Bt) crops. This strategy is based on the idea that refuges of host plants where pests are not exposed to an insecticide promote survival of susceptible pests. Despite widespread adoption of this approach, large-scale tests of the refuge strategy have been problematic. Here we tested the refuge strategy with 8 years of data on refuges and resistance to the insecticide pyriproxyfen in 84 populations of the sweetpotato whitefly (*Bemisia tabaci*) from cotton fields in central Arizona. We found that spatial variation in resistance to pyriproxyfen within each year was not affected by refuges of melons or alfalfa near cotton fields. However, resistance was negatively associated with the area

of cotton refuges and positively associated with the area of cotton treated with pyriproxyfen. A statistical model based on the first 4 years of data, incorporating the spatial distribution of cotton treated and not treated with pyriproxyfen, adequately predicted the spatial variation in resistance observed in the last 4 years of the study, confirming that cotton refuges delayed resistance and treated cotton fields accelerated resistance. By providing a systematic assessment of the effectiveness of refuges and the scale of their effects, the spatially explicit approach applied here could be useful for testing and improving the refuge strategy in other crop-pest systems.

## No Herbicide Resistance Detected in Arizona

Dr. William B. McCloskey investigates any claim of herbicide resistant weed populations in Arizona by collecting seed from suspected resistant populations and conducting herbicide trials side by side with known susceptible populations in the greenhouse. To date, there have been no confirmed instances of herbicide resistant weed populations in Arizona, including any resistance to glyphosate despite the presence of resistant weed populations in surrounding states.

## Tools for Evaluating Resistance Management Practices in Arizona

We continue to develop data, tools and resources to support evaluation of IPM adoption, resistance management, and other pest management practices. This includes development of the Arizona Pest Management Center Pesticide Use Database in partnership with the Arizona Department of Agriculture. The database contains over 20 years of historical pesticide use reports, integrated with other useful resources. This effort has received a funding boost through three successful Arizona Department of Agriculture Specialty Crop Block Grants that will partially support a database specialist position for the next 2 years. We have integrated IRAC, HRAC and FRAC mode of action tables into the database that will help facilitate resistance-related data queries. ***Impact:*** *These data are used to infer resistance risk for cross-commodity pest management, and help guide our recommendations to growers. Data were also used in part of the analysis for a study recently published in PNAS (Carrière et al. 2011).*

## Education and Outreach

*Vegetable IPM Updates.* Since January 2010, the Vegetable Crops IPM Leadership Team (Peña, Palumbo, Tickes, Matheron and Nolte) has published Veg IPM Updates on a biweekly basis. These updates deliver timely information to end-users via web, email and smart phone. Delivered 26 biweekly updates in 2011 on insect, disease and weed management, often including resistance-related topics. These reached over 450 Arizona and California stakeholders by email list, and at least 300 stakeholders via the Arizona Crop Information Site (http://ag.arizona.edu/crops/vegetables/advisories/advisories.html). In addition, the same team has produced and posted 21 vegetable IPM videos to date (8 on insects, 10 on weed control and 3 on diseases) and created video archive webpage at http://ag.arizona.edu/crops/vegetables/videos.html. Stakeholders have responded with enthusiasm about the quality and timeliness of these updates. We have seen a steady increase in attendance at educational meetings and a 2-fold increase in listserv membership for Veg IPM updates. Western Farm Press and Western Agri-Radio Network distributed these updates to over 20,000 readers.

*Field Crops IPM Shorts.* The Field Crops IPM Leadership Team (Brown, Ellsworth, Ottman, Norton, McCloskey, Mostafa and Fournier) in summer 2011 began producing short, timely advisory pieces on field crops pest management and getting these out to the broadest audience possible. "Field Crops IPM Shorts" are one-page articles on timely topics of interest that include photos, data and/or graphics. Topics so far have included natural enemies of cotton pests, selective insecticides, cotton pest thresholds, and a guide to glyphosate products for weed control and others. Some of these outputs touch on resistance topics, including one piece on Round-up Ready alfalfa. The pieces go out to at least 360 stakeholders via agent email lists, and have also been picked up each week and redistributed by Western Farm Press while some pieces have been distributed by the National Cotton Council and Southwestern Farm Press, reaching many tens of thousands of readers. The pieces are archived on the ACIS site at http://ag.arizona.edu/crops/cotton/agronomic_ipm.html.

*Arizona Crop Information Website.* The ACIS website (http://ag.arizona.edu/crops/) hosts current information and publications for clientele on crop production and pest management, including resistance issues, and is a primary outlet for Extension outputs. The site also provides clientele with information about upcoming meetings and pesticide regulatory updates. Our ACIS email list includes about 300 participants, and is used to send updates to clientele on new extension publications, emerging pest or pesticide issues and upcoming events.

*Presentations, Outreach and Continuing Education.* The Ag Team organized and delivered 28 extension meetings in FY 2011, including 6 Crop Pest Losses workshops, indoor meetings, "tent talks" and other field-based meetings. In addition, several faculty (including Ellsworth, Palumbo, Tickes and Matheron) delivered presentations at state and regional conferences including the Desert Agriculture Conference and the Southwest Agriculture Summit. At least 94 Arizona Dept. of Agriculture CEUs, 56.5 California Dept. of Pesticide Regulation CEUs and 19 Certified Crop Advisor CEUs were delivered. Attendees are very conservatively estimated at over 1,600 people. The Southwest Ag Summit held in Yuma in March 2011 attracted 760 participants including 131 students, and delivered 12 AZ, 12 CA and 12 CCA CEUs in the breakout sessions alone. Nearly every Extension presentation related to cotton or vegetable pest management in 2011 included information about resistance of key pests to insecticides and strategies for retaining efficacy of important management tools.

## References and Recent Publications

Brévault, T., Nibouche, S., Achaleke, J. and Y. Carrière. 2011. Assessing the role of non-cotton refuges in delaying *Helicoverpa armigera* resistance to Bt cotton in West Africa. Evolutionary Applications, *in press*.

Carrière, Y., Ellers-Kirk, C., Harthfield, K., Larocque, G., Degain, B., Dutilleul, P., Dennehy, T.J., Marsh, S.E., Crowder, D.W., Li, X., Ellsworth, P.C., Naranjo, S.E., Palumbo, J.C., Fournier, A., Antilla, L., Tabashnik, B.E. 2011. Large-Scale, Spatially-Explicit Test of the Refuge Strategy for Delaying Insecticide Resistance. Proceedings of the National Academy of Sciences DOI: 10.1073. http://www.pnas.org/cgi/doi/10.1073/pnas.1117851109

Chu, D., Hu, X., Gao, C., Zhao, H., Nichols, R.L., and Li, X. 2011. Use of mtCOI PCR-RFLP for Identifying Subclades of Bemisia tabaci Mediterranean Group. *J. Eco. Entomol*. (in press)

Crowder, D. W., Horowitz, A. R., Bresulauer, H., Rippa, M., Kontsedalov, S., Ghanim, M., and Y. Carrière. 2011. Niche partitioning and stochastic processes shape community structure following whitefly invasions. Basic and Applied Ecology. 12:685-694.

Dennehy, T.J., Degain, B.A., Harpold, V.S., Zaborac, M., Morin, S., Fabrick, J.A., Nichols, R. L., Brown, J.K., Byrne, F.J., & Li, X. 2010. Extraordinary Resistance to Insecticides Reveals Exotic Q Biotype of *Bemisia tabaci* (Gennadius) in the New World. Journal of Economic Entomology Dec 2010 : Vol. 103, Issue 6, pg(s) 2174-2186 doi: 10.1603/EC10239

Ellsworth, P.C. 2010. Lygus in Cotton No. 4: Chemical Control Termination Guidelines (Draft). University of Arizona Cooperative Extension Circular (peer reviewed), 2 pp. http://ag.arizona.edu/crops/presentations/DRAFT_LT_guide2-pg.pdf

Ellsworth, P.C. 2011. Cotton IPM: A Quiet Revolution Reduces Costs, Losses and Risks for Arizona's Cotton Growers. University of Arizona College of Agriculture and Life Sciences Impact Report. http://ag.arizona.edu/apmc/docs/CottonIPM2011_Impacts.pdf

Ellsworth, P., L. Brown, A. Fournier, X. Li, J. Palumbo & S. Naranjo. 2011. Keeping Cotton Green. Field Crops IPM Short. University of Arizona Cooperative Extension. http://ag.arizona.edu/crops/cotton/files/SelectiveChemicalControlsvF.pdf. July 2011

Ellsworth, P., L. Brown, A. Fournier & S. Naranjo. 2011. $1-plus Cotton: New Insect Thresholds? Field Crops IPM Short. University of Arizona Cooperative Extension. http://ag.arizona.edu/crops/cotton/files/NewThresholdsVF.pdf. June 2011

Ellsworth, P. C., A. Mostafa, L. Brown & S. Naranjo. 2011. Soft-bodied *Collops* likes soft bodies. Field Crops IPM Short. University of Arizona Cooperative Extension. http://ag.arizona.edu/crops/cotton/files/CollopsVFlo.pdf. July 2011

Fabrick, J. A., L. G. Mathew, B. E. Tabashnik and X. Li. 2011. Insertion of an intact CR1 retrotransposon in a cadherin gene linked with Bt resistance in the pink bollworm, *Pectinophora gossypiella*. Insect Mol. Biol. 20: 651-665.

Fernández-Luna, M. T., B. E. Tabashnik, H. Lanz-Mendoza, A. Bravo, M. Soberón, J. Miranda-Ríos. 2010. Single concentration tests show synergism among *Bacillus thuringiensis* subsp.

*israelensis* toxins against the malaria vector mosquito *Anopheles albimanus.* J. Invert. Pathol. 104: 231-233.

Heuberger, S., D. W. Crowder, T. Brévault, B. E. Tabashnik and Y. Carrière. 2011. Modeling the effects of plant-to-plant gene flow, larval behavior, and refuge size on pest resistance to Bt cotton. Environ. Entomol. 40: 484-495.

Heuberger, S., C. Ellers-Kirk, B. E. Tabashnik and Y. Carrière. 2010. Pollen- and seed-mediated transgene flow in commercial cotton seed production fields. PLoS ONE 5(11): e14128. doi:10.1371/journal.pone.0014128.

Heuberger, S., C. Ellers-Kirk, B. E. Tabashnik and Y. Carrière. 2011. A spatially-explicit analysis of crop-to-crop gene flow in cotton. Information Systems for Biotechnology News Report, March 2011: 5-8.

Hu, X., Dennehy, T.J., Ni, X., Zhao, H., Nichols, R.L., and Li, X. 2011. Potential adaptation of a Q biotype whitefly strain from poinsettia to field crops. Insect Science 18 (6): 719-728

Li, X., B.A. Degain, V.S. Harpold, P.G. Marcon, R.L. Nichols, A.J. Fournier, S.E. Naranjo, J.C. Palumbo and P.C. Ellsworth. 2012. Baseline susceptibilities of B- and Q-biotype Bemisia tabaci to anthranilic diamides in Arizona. Pest Management Science 2012, 68: 83–91. DOI 10.1002/ps.2227.

McCloskey, W. & L. Brown. 2011. Considering Roundup Ready$_{TM}$ Alfalfa. Field Crops IPM Short. University of Arizona Cooperative Extension. http://ag.arizona.edu/crops/cotton/files/RR-alfalfaShortF.pdf

Naranjo, S. E. 2010. Impacts of *Bt* transgenic cotton on integrated pest management. J. Agric. Food Chem. 59(11): 5842-51. (DOI:10.1021/jf102939c)

Naranjo, S.E. and P. C. Ellsworth. 2010. Fourteen years of *Bt* cotton advances IPM in Arizona. Southwest. Entomol. 35: 437-444.

Tabashnik, B. E. 2010. Communal benefits of transgenic corn. Science 330: 189-190.

Tabashnik, B. E. 2011. Pest control with Bt cotton and sterile insect releases. Information Systems for Biotechnology News Report, February 2011: 4-6.

Tabashnik, B. E. and Y. Carrière. 2011. Resistance to transgenic crops and pest outbreaks. In: Insect Outbreaks Revisited, eds. P. Barbosa, D. Letourneau and A. Agrawal: in press.

Tabashnik, B. E, F. Huang, M. N. Ghimire, B. R. Leonard, B. D. Siegfried, M. Rangasamy, Y. Yang, Y. Wu, L. J. Gahan, D. G. Heckel, A. Bravo and M. Soberón. 2011. Efficacy of genetically modified Bt toxins against insects with different mechanisms of resistance. Nature Biotechnology 29: 1128-1131.

Tabashnik, B. E., M. S. Sisterson, P. C. Ellsworth, T. J. Dennehy, L. Antilla, L. Liesner, M. Whitlow, R. T Staten, J. A. Fabrick, G. C. Unnithan, A. J. Yelich, C. Ellers-Kirk, V. S. Harpold, X. Li and Y. Carrière. 2010. Suppressing resistance to Bt cotton with sterile insect releases. Nature Biotechnology 28: 1304-1307.

Wan, P., Y. Huang, H. Wu, M. Huang, S. Cong, B. E. Tabashnik and K. Wu. 2011. Increased frequency of pink bollworm resistance to Bt toxin Cry1Ac. PLoS ONE: in press.

Williams, J. L., C. Ellers-Kirk, R. G. Orth, A. J. Gassmann, G. Head, B. E. Tabashnik and Y. Carrière. 2011. Fitness cost of resistance to Bt cotton linked with increased gossypol content in pink bollworm larvae. PLoS ONE 6 (6): e2183. doi: 10.1371/journalpone.0021863.

Zhang, H., W. Yin, J. Zhao, Y. Yang, S. Wu, B. E. Tabashnik and Y. Wu. 2011. Early warning of cotton bollworm resistance associated with intensive planting of Bt cotton in China. PLoS ONE 6(8): e22874. doi: 10.1371/journal.pone.0022874.

Colorado 2011 WERA 060 annual report

Dr. Phil Westra – Colorado State University

2011 was the year that glyphosate resistant kochia was documented at multiple locations in Colorado. In addition we confirmed glyphosate resistance in kochia samples from KS, NE, ND, and SD. A MS graduate student, Andrew Wiersma, was able to confirm that similar to Palmer amaranth, glyphosate resistance in kochia is due to amplification of the EPSPS gene in resistant plants compared to susceptible plants. The level of amplification is not as high as that documented in Palmer amaranth by my former graduate student Todd Gaines, but it is nevertheless sufficient to confer resistance to commercial glyphosate rates in the field. Resistant plants survive a lethal rate of glyphosate, produce seed, and pass the resistance trait on to their progeny. We have conducted multiple studies on the ecology of kochia seedling emergence, the longevity of buried kochia seed, and on alternative methods of kochia control. Multiple extension meeting on this topic were held in CO, KS, and NE, most in collaboration with Dr. Phil Stahlman of KSU. In addition, professional presentations were made at the 2011 Weed Science Society of America meeting, the Western Society of Weed Science Meeting, the Canadian Weed Science Society meeting, and at the North Central Weed Science Society meeting. With the collaboration of Dr. Phil Stahlman, we secured 3 years of funding in an AFRI grant to conduct research and education on glyphosate resistant kochia.
In addition, Dr. Fernando Adegas from Brazil has joined the CSU weed science group for a 1 year sabbatic to work on molecular aspects of glyphosate resistant sourgrass and horseweed.
Key personnel on our Colorado resistant weed team include Drs. Scott Nissen, Dale Shaner (ARS), Steven Chisholm, and Todd Gaines (U. of Western Australia).

**2011 WERA60 Annual Report -- GEORGIA**

Submitted by:
Katherine L. Stevenson
Department of Plant Pathology
University of Georgia

Accomplishments and impacts:

*Accomplishment:* A new rapid assay was developed for detecting tebuconazole insensitivity in the peanut early leaf spot pathogen, *Cercospora arachidicola*. *Impact:* Routine fungicide sensitivity monitoring has provided important information used in selection of fungicides for peanut disease management programs.

*Accomplishment:* Mechanisms of DMI resistance in field isolates of the peanut early leaf spot pathogen *Cercospora arachidicola* were investigated. *Impact:* Better understanding of the specific mechanisms of resistance has provided a basis for development of improved resistance management strategies for DMI fungicides in peanut disease management programs.

*Accomplishment:* Baseline sensitivity of the watermelon gummy stem blight pathogen, *Didymella bryoniae*, to the succinate-dehydrogenase-inhibiting (SDHI) fungicide penthiopyrad was established and a significant positive correlation between sensitivity to penthiopyrad and boscalid indicated a potential for cross-resistance between these related fungicides. Based on in vitro tests of isolates from fungicide-treated watermelon fields, 80% of the isolates tested were found to be insensitive to both fungicides. *Impact:* Knowledge of baseline sensitivity and cross-resistance among fungicides has enabled development of more effective programs for GSB management.

*Accomplishment:* Baseline sensitivity of the watermelon gummy stem blight pathogen, *Didymella bryoniae*, to demethylation-inhibiting (DMI) fungicides tebuconazole and difenoconazole was established. All isolates collected from fungicide-treated watermelon fields were found to be sensitive to both DMI fungicides. *Impact:* Knowledge of baseline sensitivity to DMI fungicides has provided the basis for an effective resistance monitoring program to evaluate resistance management strategies and detect significant changes in sensitivity of the GSB pathogen to these highly effective fungicides.

*Accomplishment:* Field experiments demonstrated that a high frequency of insensitivity of *Didymella bryoniae* to azoxystrobin, boscalid or thiophanate-methyl was associated with poor control of gummy stem blight in watermelons treated with the respective fungicides. *Impact:* The relationship between the frequency of fungicide resistance and level of disease control has enabled development of more effective programs for GSB management based on fungicide sensitivity monitoring.

*Accomplishment:* Investigations were conducted on the molecular characterization of boscalid- and penthiopyrad-resistant isolates of *Didymella bryoniae* and assessment of their sensitivity to fluopyram. *Impacts:* Better understanding of the specific mutations associated with resistance to SDHI fungicides has provided a basis for development of improved resistance management strategies for SDHI fungicides in watermelon gummy stem blight management programs.

Publications:

Avenot, H. F., Thomas, A., Gitaitis, R. D., Langston, D. B., Jr., and Stevenson, K. L. 2010. Molecular characterization of resistance to boscalid and penthiopyrad in *Didymella bryoniae* isolates collected from Georgia watermelon fields. Phytopathology 100:S9.

Avenot, H. F., Lewis, K. J., Brenneman, T. B., and Stevenson, K. L. 2011. Development of a PCR-based assay for QoI resistance monitoring in the pecan scab pathogen, *Fusicladium effusum*. Phytopathology 101:S11.

Avenot, H., Thomas, A., Gitaitis, R. D., Langston, D. B. Jr., and Stevenson, K. L. 2011. Molecular characterization of boscalid- and penthiopyrad-resistant isolates of *Didymella bryoniae* and assessment of their sensitivity to fluopyram. Pest Management Science. DOI 0.1002/ps.2311.

Qiu, J., Stevenson, K. L., and Culbreath, A. K. 2009. A new rapid assay for detecting tebuconazole resistance in *Cercospora arachidicola*. Proceedings of the American Peanut Research and Education Society. vol. 41.

Qiu, J., Culbreath, A. K., and Stevenson, K. L. 2010. A new rapid assay for detecting tebuconazole resistance in *Cercospora arachidicola*. Phytopathology 100:S105.

Qiu, J., Culbreath, A. K., and Stevenson, K. L. 2010. Mechanisms of DMI resistance in field isolates of *Cercospora arachidicola*. Phytopathology 100:S105.

Seyran, M., Nischwitz, C., Lewis, K., Gitatitis, R., Stevenson, K., and Brenneman, T. 2009. Taxonomy of the pecan scab fungus based on the cytochrome b gene sequence. Phytopathology 99:S200.

Seyran, M., Nischwitz, C., Lewis, K. J., Gitaitis, R. D., Brenneman, T. B., and Stevenson, K. L. 2009. Phylogeny of the pecan scab fungus *Fusicladium effusum* G. Winter based on the cytochrome b gene sequence. Mycological Progress 9:305-308.

Seyran, M., Brenneman, T. B., and Stevenson, K. L. 2010. In vitro toxicity of alternative oxidase inhibitors salicylhydroxamic acid and propyl gallate on *Fusicladium effusum*. Journal of Pest Science 83:421-427.

Seyran, M., Brenneman, T. B., Stevenson, K. L. 2010. A rapid method to monitor fungicide sensitivity in the pecan scab pathogen, *Fusicladium effusum*. Crop Protection. Crop Protection 29:1257-1263.

Stevenson, K. L., Seyran, M., and Brenneman, T. B. 2009. Monitoring fungicide resistance in the pecan scab pathogen. Proceedings of the Southeastern Pecan Growers Association 102:62-67.

Stevenson, K. L., Brenneman, T. B., and Seyran, M. 2009. Monitoring fungicide resistance in individual orchard populations of the pecan scab fungus, *Fusicladium effusum*. Pages 156-157 in: Proceedings of the 10th International Epidemiology Workshop, D. M. Gadoury, R. C. Seem, M. M. Moyer, and W. E. Fry (Eds.). New York State Agricultural Experiment Station, Geneva, NY.

Stevenson, K. L., Seyran, M., and Brenneman, T. B. 2009. Monitoring fungicide resistance in the pecan scab pathogen. Proceedings of the Southeastern Pecan Growers Association 102:62-67.

Stevenson, K. L., Brenneman, T. B., and Seyran, M. 2009. Monitoring fungicide resistance in individual orchard populations of the pecan scab fungus, *Fusicladium effusum*. Pages 156-157 in: Proceedings of the 10th International Epidemiology Workshop, D. M. Gadoury, R. C. Seem, M. M. Moyer, and W. E. Fry (Eds.). New York State Agricultural Experiment Station, Geneva, NY.

Stevenson, K. L., Keinath, A. P., Thomas, A., Langston, D. B., Roberts, P. D., Hochmuth, R. C., and Thornton, A. C. 2011. Boscalid insensitivity documented in *Didymella bryoniae* isolated from watermelon in Florida and North Carolina. *Plant Health Progress*. (Submitted)

Thomas, A., Langston, D. B., Jr., and Stevenson, K. L. 2010. Sensitivity of *Didymella bryoniae* to DMI and carboxamide fungicides. Phytopathology 100:S126.

Thomas, A., Langston, D. B. Jr., and Stevenson, K. L. 2012. Baseline sensitivity and cross-resistance within succinate-dehydrogenase-inhibiting fungicides and demethylation-inhibiting fungicides in *Didymella bryoniae*. Plant Disease (Accepted).

Accomplishments:
Have been part of a Weed Science Society of America effort to create and distribute herbicide resistance training materials via the web and to increase efforts with regulatory and industry officials to include site of action labeling for herbicides.

Accomplishments:
Have characterized glyphosate-resistant and multiple herbicide resistant populations of Palmer amaranth across the state of Georgia. We have identified Palmer amaranth popularions resistant to glyphosate, ALS-inhibitors, atrazine, and dinitroaniline herbicides. We are in the process of mapping the basis of target and non-target site ALS resistance in Palmer amaranth in Georgia.

Pertinent Publications:
Gaines, T.A., W. Zhang, D. Wang, B. Bukun, S.T. Chisholm, D.L. Shaner, S.J. Nissen, W.L. Patzoldt, P.J. Tranel, A.S. Culpepper, T.L. Grey, T.M. Webster, W.K. Vencill, R.D. Sammons, J. Jiang, C. Preston, J.E. Leach, and P. Westra. 2010. Gene amplification confers glyphosate resistance in *Amaranthus palmeri*. PNAS 107:955-956.

Vencill, W.K., R.L. Nichols, T.M. Webster, C.M. Mallory-Smith, N. Burgos, J. Soteres, and W.G. Johnson. 2011. Review of the evolution of herbicide resistance in crops and weeds. Weed Sci. (In Press).

Vencill, W.K., R.N. Nichols, T.M. Webster, J. Soteres, W.G. Johnson, N. Burgos, and C. Mallory-Smith. 2010. Herbicide Resistance: An Historical Perspective. Symposium of Herbicide Resistance. Asbtr. Weed Sci. Soc. Am.

Vencill, W.K. and J. Whitaker. 2011. Dinitroaniline-resistant Palmer amaranth in Georgia. Proc. Beltwide Cotton Conf., Atlanta, GA.

Vencill, W.K. 2011. A framework for defining herbicide-resistant weed biotypes. Proc. Weed Sci. Soc. Am. Portland, OR. Abstract # 288.

**MN State Report for WERA-060**

**Title:** Novel Vip3A *Bacillus thuringiensis* (Bt) maize approaches high dose efficacy against *Helicoverpa zea* (Lepidoptera: Noctuidae) under field conditions: Implications for resistance management

**Authors:** E. C. Burkness, G. P. Dively, T. Patton, A. C. Morey, and W. D. Hutchison

**Abstract:** Sweet corn, *Zea mays* L., transformed to express a novel vegetative insecticidal protein, Vip3A (event MIR162, Syngenta Seeds, Inc.) produced by the bacterium, *Bacillus thuringiensis* (Bt), was evaluated over four field seasons in Maryland and two field seasons in Minnesota for efficacy against the corn earworm, *Helicoverpa zea* (Boddie). Hybrids expressing the Vip3A protein and pyramided in hybrids also expressing the Cry1Ab Bt protein (event Bt11, ATTRIBUTE®, Syngenta Seeds, Inc.) were compared to hybrids expressing only Cry1Ab or to genetically similar non-Bt hybrids each year. In addition to *H. zea* efficacy, results for *Ostrinia nubilalis* (Hübner) and *Spodoptera frugiperda* (J.E. Smith) are presented. Over all years and locations, the non-Bt hybrids, without insecticide protection, averaged between 43 and 100% ears infested with a range of 0.24 to 1.74 *H. zea* larvae per ear. By comparison, in the pyramided Vip3A x Cry1Ab hybrids, no larvae were found and only minimal kernel damage (likely due to other insect pests) was recorded. Hybrids expressing only Cry1Ab incurred a moderate level of *H. zea* feeding damage, with surviving larvae mostly limited to the first or second instar as a result of previously documented growth inhibition from Cry1Ab. These results suggest that the Vip3A protein, pyramided with Cry1Ab, appears to provide the first "high-dose" under field conditions and will be valuable for ongoing resistance management.

**Citation:** Burkness E. C., G. P. Dively, T. Patton, A. C. Morey, and W. D. Hutchison. 2010. Novel Vip3A *Bacillus thuringiensis* (Bt) maize approaches high dose efficacy against *Helicoverpa zea* (Lepidoptera: Noctuidae) under field conditions: Implications for resistance management. GM Crops 1 (5): 337-343.
(On-line: http://www.landesbioscience.com/journals/gmcrops/archive/volume/1/issue/5/ )

**Title:** Cross-Pollination of Nontransgenic Corn Ears With Transgenic Bt Corn: Efficacy Against Lepidopteran Pests and Implications for Resistance Management

**Authors:** E. C. Burkness, P. K. O'Rourke, and W. D. Hutchison

**Abstract:** The efficacy of nontransgenic sweet corn, *Zea mays* L., hybrids cross-pollinated by *Bacillus thuringiensis* (Bt) sweet corn hybrids expressing Cry1Ab toxin was evaluated in both field and laboratory studies in Minnesota in 2000. Non-Bt and Bt hybrids (maternal plants) were cross-pollinated with pollen from both non-Bt and Bt hybrids (paternal plants) to create four crosses. Subsequent crosses were evaluated for efficacy in the field against European corn borer, *Ostrinia nubilalis* (Hϋbner), and corn earworm, *Helicoverpa zea* (Boddie), and in laboratory bioassays against *O. nubilalis*. Field studies indicated that crosses with maternal Bt plants led to

low levels of survival for both *O. nubilalis* and *H. zea* compared with the non-Bt X non-Bt cross. However, the cross between non-Bt ears and Bt pollen led to survival rates of 43 and 63% for *O. nubilalis* and *H. zea* larvae, respectively. This intermediate level of survival also was reflected in the number of kernels damaged. Laboratory bioassays for *O. nubilalis*, further confirmed field results with larval survival on kernels from the cross between non-Bt ears and Bt pollen reaching 60% compared with non-Bt crossed with non-Bt. These results suggest that non-Bt refuge plants, when planted in proximity to Bt plants, and cross-pollinated, can result in sublethal exposure of *O. nubilalis* and *H. zea* larvae to Bt and may undermine the high-dose/refuge resistance management strategy for corn hybrids expressing Cry1Ab.

**Citation:** Burkness, E.C., P.K. O'Rourke, and W.D. Hutchison. 2011. Cross pollination of nontransgenic corn ears with transgenic Bt corn: Efficacy against Lepidopteran pests and implications for resistance management. J. Econ. Entomol. 104(5): 1476-1479.
DOI: http://dx.doi.org/10.1603/EC11081

WERA-060 Annual Report for New Jersey
Andy Wyenandt
Extension Specialist in Vegetable Pathology
Department of Plant Biology and Pathology
Rutgers University

Fungicide resistance management in vegetable crop production continues to be a major focus in New Jersey as well as the rest of the mid-Atlantic region (PA, DE, MD, and VA). The 6$^{th}$ edition of the Fungicide Resistance Management Guidelines for Vegetable Crop Production in the mid-Atlantic Region will be published in 2011. Since 2007, over 10,000 of these guides have been distributed to growers, extension agents and specialists, crop consultants, and industry representatives throughout the region representing to our best estimates between 75,000 to 100,000 A of commercial vegetable production.

Publications:

Wyenandt, A. and N.L. Maxwell. 2011. Evaluating vegetable fungicide recommendations in the United States: Should more be done to limit the risks of fungicide resistance development? Online. Journal of Extension. June 2011. <http://www.joe.org/joe/2011june/a8.php>

New York

## 2011 Progress Report for WERA-060
## Cornell University

**Jeffrey Scott**

Permethrin Resistance in House Flies

1) Accomplishments
We investigated the promoter of CYP6D1 to better understand the molecular basis for overtranscription of this P450 that results in permethrin resistance in house flies. While we were able to identify the promoter region responsible for increased transcription in the resistant strain, the factor binding to that region remained elusive.

2) Impacts
Monitoring multiple loci that contribute to insecticide resistance represents a significant technical challenge. Understanding of the mechanisms involved in the overexpression of CYP6D1 leading to permethrin resistance will lead to improved methods for monitoring this resistance mechanism in field populations.

3) Publications.

Lin, G. G.-H. and Scott, J. G. 2011. Investigations of the constitutive overexpression of *CYP6D1* in the permethrin resistant LPR strain of house fly (*Musca domestica*). Pestic. Biochem. Physiol. 100: 130-134.

Lin, G. G.-H., Kozaki, T. and Scott, J. G. 2011. Hormone receptor-like in 96 and broad-complex modulate phenobarbital induced transcription of cytochrome P450 *CYP6D1* in *Drosophila* S2 cells. Insect Molec. Biol. 20:87-95.

### Margaret Tuttle McGrath

FUNGICIDE RESISTANCE IN CUCURBIT POWDERY MILDEW

Activities pertaining to fungicide resistance in cucurbit powdery mildew being conducted in New York are monitoring of resistance in production fields, evaluating fungicides at-risk for resistance, and determining baseline sensitivity for new fungicides. Fungicides are an important tool for managing cucurbit powdery mildew to avoid losses in quantity and/or fruit quality. This is the most common disease of cucurbit crops, which include pumpkin, squash and melon. Effective control necessitates products able to move to the lower leaf surface, where this disease develops best. Unfortunately these mobile products are prone to resistance development because of their single-site mode of action. Spores of this pathogen can be wind dispersed long distances enabling widespread dispersal of resistant strains.

A leaf disk bioassay was used to examine fungicide sensitivity of pathogen isolates (individuals) obtained at the end of the growing season in 2010 from commercial pumpkin crops and research fields. Almost all 96 isolates (97%) tested with Topsin M were resistant to this fungicide group (MBC; FRAC code 1). Resistance to QoI fungicides (FRAC code 11) was detected in 98% of the isolates tested. Resistance to both fungicide groups was also found to be common in previous years. Resistance to both is qualitative, thus pathogen isolates are either sensitive or resistant, and fungicides are ineffective against resistant isolates. There is a fungicide (Pristine) with a FRAC code 11 active ingredient that has continued to be recommended because it contains another active ingredient (FRAC code 7). Applying Pristine could select for pathogen strains resistant to FRAC code 11 fungicides, thereby maintaining this resistance in the pathogen population. The very high frequency of resistance to FRAC code 1 fungicides, despite very limited use for other pathogens, indicates that there is no ‘fitness cost’ of this trait that would cause resistant strains to be at a competitive disadvantage with sensitive strains in the pathogen population. Ability to grow on leaf disks with a high concentration (500 ppm) of boscalid, an active ingredient in Pristine, was detected in 43% of the pathogen isolates tested. This concentration is in the range of what would be in the spray tank when Pristine is applied at labeled rates, therefore isolates tolerating 500 ppm are likely fully resistant to this fungicide, which means they would not be controlled by Pristine. Isolates collected in 2010 were more sensitive to the other fungicides tested, which represent the other two fungicide chemistries recommended for managing cucurbit powdery mildew. Myclobutanil, the active ingredient in Rally, a FRAC code 3 fungicide, at 20 ppm was tolerated by 47% of the isolates. Only 11% were insensitive to 80 ppm myclobutanil. Quinoxyfen, the active ingredient in Quintec, a FRAC code 13 fungicide, at 10 ppm was tolerated by 42% of the isolates. One isolate tested was insensitive to 80 ppm myclobutanil and also to 40 ppm quinoxyfen as well as being fully resistant to boscalid and code 1 and 11 fungicides. Existence of pathogen isolates like this one with resistance or elevated insensitivity (compared to other isolates) to all labeled fungicide chemistries is a concern for continued effective management of cucurbit powdery mildew with currently-registered fungicides. Further evolution could result in development of full (practical) resistance to all fungicides.

A seedling fungicide sensitivity bioassay developed in NY was used again in 2011 to monitor pathogen sensitivity to fungicides in commercial and research fields of cucurbits. Similar to previous years, resistance to FRAC Code 1 and Code 11 fungicides were detected in all populations examined, typically at high levels. Resistance to these chemistries is qualitative and cross resistance occurs amongst all fungicides in each group. Strains of the pathogen were detected able to tolerate 500 ppm boscalid (active ingredient in Pristine), 120 ppm myclobutanil (Rally) and 10 ppm quinoxyfen (Quintec). Ability to tolerate 500 ppm boscalid is of concern because this concentration is in the range of what would be in the spray tank when Pristine is applied. Resistance is common to the other active ingredient in Pristine, which is in FRAC code 11. Therefore Pristine would not be expected to be able to control these strains. On average, a lower proportion of the pathogen populations were able to tolerate 10 ppm quinoxyfen than 500 ppm boscalid or 120 ppm myclobutanil. The proportion was lowest for 10 ppm quinoxyfen. Therefore Quintec was expected to be the most effective fungicide in 2011. Four FRAC Code 3 (DMI) fungicides were included in the bioassays at the same dose (40 ppm) to assess whether there are inherent differences in activity among fungicides in this chemical group. Only minor differences were detected which were not considered to be important. The fungicides tested were Rally, Procure, Tebuzol and Inspire. There are differences in the dose that can be applied to crops with these. The dose in the spray tank when these fungicides are applied at the highest labeled rate at 50 gpa are 263 ppm for Inspire Super, 300 ppm for Rally, 363 ppm for Tebuzol, and 527 ppm for Procure.

Efficacy of fungicides at-risk for resistance was determined by conducting a replicated experiment with fungicides applied to field-grown pumpkin exposed to naturally-occurring pathogen population. Powdery mildew started to develop earlier than expected compared to similar previous experiments with this variety based on both plant growth stage and calendar date. On 1 August, two days before treatments were started, powdery mildew was observed on 1 to all 8 older leaves examined in all but 2 of the 64 plots; overall incidence of affected leaves was 75%. Thus when treatments were started on 3 August powdery mildew in all plots greatly exceeded the IPM threshold of one affected leaf out of 50 old leaves. In contrast, only 5% of leaves were affected on 2 Aug 2010 in a similar experiment with the same variety planted on the same day. Efficacy of treatments may have been impacted by applications starting after the IPM threshold. Based on AUDPC values (Area Under Disease Progress Curve) for upper leaf surfaces, the most effective fungicides were four new products: Luna Experience, Torino SC, Mervion (higher rate), and Fontelis SC. Treatments with these products had the lowest AUDPC values for lower leaf surfaces. These fungicides were not significantly more effective than currently registered mobile fungicides with single site mode of action: Pristine, Quintec, and Procure.

**2011 Publications**

McGrath, M. T. 2011. Challenge of fungicide resistance in managing vegetable diseases in United States and anti-resistance strategies. Chapter 16. Pages 191-207. In Fungicide Resistance in Crop Protection: Threat and Management. Thind, T. S. (Ed.). CABI International.

McGrath, M. T. and Hunsberger, L. K. 2011. Effectiveness for cucurbit powdery mildew of fungicides prone to resistance development. Phytopathology 100:S (abstract for presentation made 10/10).

McGrath, M. T., and Hunsberger, L. K. 2011. Efficacy of fungicides for managing cucurbit powdery mildew and pathogen sensitivity to fungicides, 2010. Plant Disease Management Reports 5:V104.

McGrath, M. T., Rivara, K. L., and Hunsberger, L. K. 2011. Sensitivity of the cucurbit powdery mildew pathogen to fungicides prone to resistance development. Phytopathology 100:S (abstract for presentation made 10/10)