

Overview of Apple Resources at Cornell University

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The depth and breadth of apple resources at Cornell is tremendous in its diversity of topics covered and expertise available, in both research and extension. Funding from the industry aids our research and outreach efforts, and our talented Cornell Cooperative Extension staff extends this information fur-

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ther. From breeding of scions and rootstocks, control of pests and pathogens, optimizing growth and quality, through to food processing – our industry and consumers benefit from this research. The following overview is presented as a brief summary of the apple resources available through our programs.

Cornell Cooperative Extension (CCE)

The Lake Ontario Fruit (LOF) Team: Debbie Breth (Team Leader, and Integrated Pest Management; retiring March 31, 2016, but position to be refilled), Mario Sazo (Cultural Practices), Craig Kahlke (Fruit Quality Management), Matt Wells (Production Economics & Business Management) host the Lake Ontario winter fruit schools and summer tours. They wrote a guide on Apple IPM for beginners (<http://www.fruit.cornell.edu/orchard-ipm/index.html>). Eastern New York Commercial Horticulture Program members working in apples include Dan Donahue (Hudson Valley), Anna Wallis (Northern NY) and Bob Weybright (Agriculture Business Development Specialist). CCE staff is actively involved in programming and presenting at the Empire State Producers Expo held annually in Syracuse, NY, writing newsletters and harvest maturity reports, and also hosting their own fruit schools, including the Northeastern NY Commercial Tree Fruit School and the Hudson Valley Commercial Fruit Growers School. In Long Island, Daniel Gilrein, Faruque Zaman, and Andrew Senesac (Weed Science) conduct research and assist in tree fruit extension.

- Sazo, M. M., and Robinson, T. L. 2015. Measuring and extending the benefits of orchard mechanization in high-density orchards in western NY. *New York Fruit Quarterly* 23(2): 25–28.

Entomology

Insect Control in Tree Fruits (Art Agnello):

Art’s research is focused on solving insect control problems in tree fruits and assessment of seasonal management programs, using a range of tactics: sampling and monitoring techniques, IPM/biological studies, insecticides (efficacy evaluation of new products under development), implementation of currently labeled selective reduced-risk insecticides, testing tactics and products for organic apple production. He also does work on pesticide application technology, pheromone mating disruption (evalua-

tion of new products and dispenser technologies, determining best methods of incorporation into commercial production); biological control (use of entomopathogenic nematodes to help control a native weevil in apples); and invasive and exotic pests (e.g., brown marmorated stink bugs; spotted wing *Drosophila*; monitoring for exotic species). Additionally, Art has focused on ambrosia beetles: monitoring, distribution, and management tactics using pesticides and biologicals.

Art’s extension responsibility is to provide arthropod pest management recommendations to the tree fruit industry. He is the coordinator and editor of the Cornell Pest Management Guidelines for Commercial Tree Fruit Production [<http://ipm-guidelines.org/treefruits/>], and the editor of “Scaffolds,” a weekly online fruit newsletter [<http://www.scaffolds.entomology.cornell.edu/>]. He speaks at multiple grower meetings, fruit schools, field meetings, research and extension conferences, and international conferences. He is co-chair of the CCE Fruit Program Work Team, co-chair of the NE IPM Tree Fruit Working Group [<http://www.northeastipm.org/working-groups/tree-fruit/>], and interim editor of the New York Fruit Quarterly [<http://www.nyshs.org/fq.php>].

- Agnello, A., Breth, D., Tee, E., Cox, K., and Warren, H. R. 2015. Ambrosia beetle – an emergent apple pest. *New York Fruit Quarterly* 23(1): 25–28.
- Agnello, A., Jentsch, P., Shields, E., Testa, T., and Keller, M. 2014. Evaluation of persistent entomopathogenic nematodes for biological control of plum curculio. *New York Fruit Quarterly* 22(1): 21–24.
- Kain, D. P., and Agnello, A. M. 2013. Relationship between plant phenology and *Campylomma verbasci* (Hemiptera: Miridae) damage to apple fruit. *Environ. Entomol.* 42(2): 307–313.

The Danforth Lab in Ithaca studies Bees (Bryan Danforth):

Some of the research most relevant to apples are studies of the role of native pollinators.

- Danforth, B. N., and van Dyke, M. 2015. The wild bees of New York: Our insurance policy against honey bee decline. *New York Fruit Quarterly* 23(4): 17–22.
- Park, M. G., Raguso, R. A., Losey, J. E., and Danforth, B. N. 2015. Per-visit pollinator performance and regional importance of wild *Bombus* and *Andrena* (*Melandrena*) compared to the managed honey bee in New York apple orchards. *Apidologie* 1–16. [DOI: 10.1007/s13592-015-0383-9]
- Park, M., Danforth, B., Losey, J., Biddinger, D., Vaughan, M., Dollar, J., Rajotte, E., and Agnello, A. 2012. Wild pollinators of Eastern apple orchards and how to conserve them. Cornell Univ. / Northeastern IPM Center. 20 pp. <http://www.northeastipm.org/park2012>

Management of Arthropods in Crops and Natural Systems (Jan Nyrop):

The broad goal of Jan’s research is to develop concepts and

tools needed to improve management of arthropods in crops and natural systems. He is especially interested in improving the effectiveness of natural enemies for controlling pests, in improving how decisions are made to control pests, and in applying quantitative tools to better understand the ecology of arthropod pests and the plants they feed upon. Biological control work has focused on understanding the basis for an outcome of plan-mediated interactions between pest and predator mites. Research in decision-making has addressed the optimal allocation of resources to monitor invasive species. Quantitative ecology work has focused on understanding, through simulation and mathematical modeling, how pest attraction to a trap crop and retention of these organisms by a trap crop influence the overall effectiveness of trap cropping as a pest management strategy. Jan has been co-teaching a course entitled “Invasions: Trading Species in a Shrinking World”, in collaboration with Ann Hajek. His extension efforts focus on biological control and developing pest management guidelines that promote sustainability.

Pesticide Application Technology (Andrew Landers and Research Associate Tomàs Pallejà Cabré):

The goal of Andrew’s program is to develop methods to improve deposition within the fruit canopy and reduce off-target drift. Research includes the factors affecting airflow, speed and direction within the canopy. They develop new methods to apply pesticides precisely, such as the use of GPS, GIS, RFID, etc., and improve traceability and management of sprayers. Their research thrust is on developing precision spraying techniques for horticultural crops. They have also developed a fully automatic sprayer controller for adjusting liquid and airflow on orchard and vineyard sprayers. They show growers, via field demonstrations, workshops and conference presentations how to monitor pesticide use, air direction and droplet penetration. Presentations are made nationally and internationally each year. Andrew prepares a chapter on application technology for six Cornell Pest Management Guidelines each year. These are distributed through regional extension offices and posted online at: <https://store.cornell.edu/c-875-pmep-guidelines.aspx>. Website at <http://web.entomology.cornell.edu/landers/pestapp/>.

- Landers, A., Zhai, C., Llorens, J., and Larzelere, W. 2015. The development of a spray monitoring system for fruit crops as an aid to farm management and traceability. *Julius-Kühn-Archiv* 448: 74.
- Pallejà, T. and Landers, A. J. 2015. Real time canopy density estimation using ultrasonic envelope signals in the orchard and vineyard. *Computers and Electronics in Agriculture* 115: 108–117.
- T. Pallejà, and Landers, A. 2014. Precision spraying in the orchard and vineyard: Measuring canopy density. *New York Fruit Quarterly* 22(4): 15–17.

Insect Behavior and Chemical Communication Systems (Charles Linn, Senior Research Associate):

Current projects include: 1) Defining host fruit volatile blends for different parasitoid wasps that specialize on different *Rhagoletis pomonella* fly populations, 2) testing a protocol for rapid identification of cryptic *Rhagoletis* flies infesting different host fruit in the western U.S. to determine whether *R. pomonella* is infesting domestic apples in that region, 3) identifying host plant volatiles used by specialist and generalist moth species, testing

a model for host specialization, 4) identifying volatiles from the surface of plant tissues (shoots and fruit) that are produced by microbial agents and contributing to the volatile profile used by insects for host location, and 5) identifying below-ground volatiles and their sources that are involved in insect herbivory. All projects are collaborative.

Food Science

Food Safety and Good Agricultural Practices (Betsy Bihn, Senior Extension Associate):

Betsy is the director of the Produce Safety Alliance (www.producesafetyalliance.cornell.edu) and program coordinator for the National Good Agricultural Practices (GAPs) Program. She will be actively involved in the new Institute for Food Safety at Cornell. Her primary focus is to help fruit and vegetable growers implement produce safety practices to reduce microbial food safety risks, meet buyer demand for food safety practices including third party audits, and comply with new regulatory requirements that are part of the Food Safety Modernization Act’s Rule for Produce Safety. Her research focus has been on the microbial quality of water used to produce fruits and vegetables. Betsy’s extension program in NY is known for its multi-day GAPs training program that includes growers developing their own farm food safety plans (Figure 1). This training is in collaboration with CCE and NYSDAM.

- Bihn, E. A., Wszelaki, A. L., Schermann, M. A., Wall, G. L., and Amundson, S. K. 2014. Farm food safety decision trees for fruit and vegetable growers (a training manual). 187 pp. Cornell University / National GAPs Program.
- Wall, G. L., and Bihn, E. A. 2015. Recommendations to regulations: Managing wildlife and produce safety on the farm. *Food Safety Risks from Wildlife: Challenges in Agriculture, Conservation, and Public Health*. Michele T. Jay-Russell, Michael P. Doyle (eds.). Springer, New York.
- National GAPs Program [www.gaps.cornell.edu]. This website houses a collections of educational materials to help growers assess risks and implement produce safety practices on their farms. It also has a complete research and extension database with access to scientific literature and contact information for GAPs Collaborators nationwide.



Figure 1. Betsy Bihn conducting an outreach class on food safety.

Cornell Enology Extension Lab (CEEL) (Chris Gerling):

Chris is an extension associate in CEEL. He manages the Vinification and Brewing Laboratory as well as the NY Wine Analytical Lab, and creates educational programs for producers of fermented cider, wine, and distilled spirits. Chris hosts cider workshops and is conducting a study of sensory characteristics of single varietal ciders in contrast to commercially available ciders. He works with the wine, (fermented) cider and distilled spirits industries, with the goal of increasing quality, profitability and sustainability. Chris focuses mainly on beverage production from the time the fruit is harvested until the final product is bottled. CEEL activities include research fermentation trials, evaluation of new varieties, service lab analyses, short courses and workshops.

Enology and Fermented Beverages (Anna Katharine Mansfield):

Anna Katharine's work centers on wine production and sensory evaluation, but often overlaps with related activities, like wine marketing and the production of other fermented beverages (cider, beer, and spirits.)

Food Safety, Microbiology and UV-pasteurization (Randy Worobo):

Randy's research and extension programs are focused on enhancing the microbiological safety and quality of fruit and vegetable products. A large portion of his research is dedicated to evaluating new food processing technologies, such as ultraviolet light, high-pressure processing, and antimicrobials, to enhance the safety and quality of post harvest produce. The primary focus of his extension and outreach activities is to provide food safety training and direct assistance to the food and beverage industries. His extension training program includes certification training for Juice HACCP, current Good Manufacturing Practices, and basic food and beverage sanitation. Randy developed a UV pasteurization system, widely used by cider producers to produce safe cider products, without the influence on taste that heat pasteurization may impart.

- Usaga, J., Worobo, R. W., Moraru, C. I., and Padilla-Zakour, O. I. 2015. Time after apple pressing and insoluble solids influence the efficiency of the UV treatment of cloudy apple juice. *LWT-Food Science and Technology* 62(1): 218–224.
- Dong, Q., Manns, D.C., Feng, G., Yue, T., Churey, J. J., and Worobo, R. W. 2010. Reduction of patulin in apple cider by UV radiation. *Journal of Food Protection* 73: 69–74.

Food Chemistry and Human Health (Rui Hai Liu):

Dr. Liu's research program focuses on diet and cancer, effect of functional foods/nutraceuticals on chronic disease risks, bioactive compounds in natural products, and herbal remedies for anticancer and antiviral activity. Specific interests include: 1) health benefits of phytochemicals in fruits, vegetables and whole grains; 2) food genomics and functional foods for disease prevention and health promotion targeted at cancers, aging, and inflammatory diseases. Some of his apple publications include:

- Boyer, J., and Liu, R. H. 2004. Apple phytochemicals and their health benefits. *Nutrition Journal* 3(5): 12.
- Liu, R. H. 2013. Health-promoting components of fruits and vegetables in the diet. *Advances in Nutrition* 4(3): 384S–392S.

- Nayak, B., Liu, R. H., and Tang, J. 2015. Effect of processing on phenolic antioxidants of fruits, vegetables, and grains –A review. *Critical Reviews in Food Science and Nutrition* 55: 887–918.

Processing and Value-Added Products of Agricultural Commodities: (Olga Padilla-Zakour):

Olga directs the NYS Food Venture Center, a major extension program of the Department of Food Science. She coordinates and develops outreach programs and activities to support new and established entrepreneurs, processors and farmers introducing new products. She provides guidelines and assists in regulatory issues to ensure the safety of food products and acts as Process Authority to schedule process documentation to comply with federal and state regulatory requirements for new products (more than 1000 products per year). She develops and implements training programs for food entrepreneurs and organizes and teaches Better Process Control Schools annually. She develops and maintains the Northeast Center for Food Entrepreneurship at the Food Venture Center website: <http://necfe.foodscience.cornell.edu/>

Olga's research program focuses on applied research in support of her extension program to add value and safety to agricultural commodities. Emphasis is on developing new products/processes, improving or retaining quality in processed foods, increasing economic viability of farm-based ventures, and identifying the key factors that affect the safety of specialty foods manufactured by small-scale processors.

- Athiphunamphai, N., Bar, H. Y., Cooley, H. J., and Padilla-Zakour, O. I. 2014. Heat treatment and turbo extractor rotational speed effects on rheological and physico-chemical properties of varietal applesauce. *Journal of Food Engineering* 136: 19–27.

Horticulture

Apple Breeding (Susan Brown):

The apple breeding program spans basic to applied research, with an emphasis on improving consistency of quality in advanced selections as potential apple varieties. 'SnapDragon™' and 'RubyFrost™' apples were released in concert with Crunch Time Apple Growers to offer New York State apple growers an exclusive license. Breeding goals included freedom from or reduction in storage disorders, slow flesh browning for fresh cut, improved nutritional properties, exceptional quality, and where possible, resistance to disease (Figure 2). Susan is part of RosBREED, and benefits from genotyping parents for traits such as acidity, bitter pit susceptibility, and other traits that allow her to predict the best combinations for crossing for new variety development. This program benefits from collaborations with Plant Pathology researchers, horticulturist Chris Watkins, and from access and research at the USDA/ARS. Graduate students and summer scholars add to the knowledge of genetic improvement. Kevin Maloney assists in all aspects of testing and trials.

- Brown, S. K., and Maloney, K. E. 2015. Apple Breeding, Genetics and Genomics. *New York Fruit Quarterly* 23(3): 5–7.

Nutrition Physiology and Stress Physiology, Sugar and Acid Accumulation and Metabolism (Lailiang Cheng):

Lailiang's group is focused on how nitrogen supply affects carbon metabolism and nitrogen metabolism in both apples



Figure 2. Tasting new apple varieties at a meeting of the Great Lakes Fruit Workers.

and grapes. Pome fruits of the Rosaceae family, such as apple, are unique in that sorbitol serves as a primary end-product of photosynthesis and a major translocated carbohydrate in the phloem. Sorbitol is also implicated in responses to environmental stresses. Apple trees with decreased sorbitol synthesis are being used to understand the role sorbitol plays in carbohydrate metabolism, organic acid metabolism and nitrogen metabolism, and stress tolerance. They are very interested in both primary metabolism and secondary metabolism relevant to fruit quality during fruit growth and development, as well as their responses to nutrient stress and other environmental stresses. Sugar/acid accumulation and metabolism in apple fruit is one of the foci of current work. On the more applied side, research addresses uptake, translocation, storage, and remobilization and demand-supply relationship of nitrogen and other nutrients in apples and grapevines to provide a basis for optimizing nutrient inputs into both apple orchards and vineyards.

The goal of their extension program is to effectively deliver research-based, up-to-date information and expertise concerning nutrient management to the apple industry in New York through collaborations with faculty, extension educators, and growers. A current focus is management of nitrogen, potassium, calcium and other essential nutrients to improve yield and quality of high-density apple plantings.

- Li, M., Feng, F., and Cheng, L. 2012. Expression patterns of genes involved in sugar metabolism and accumulation during apple fruit development. *PLoS One*. 7:e33055.
- Wu, T., Wang, Y., Zheng, Y., Fei, Z., Dandekar, A. M., Xu, K., ... and Cheng, L. 2015. Suppressing sorbitol synthesis substantially alters the global expression profile of stress response genes in apple (*Malus domestica*) leaves. *Plant and Cell Physiology* pcv092.

Postharvest Physiology (Chris Watkins, Professor, and Director of Cornell Cooperative Extension):

Chris conducts a postharvest science research program with a major focus on apple. His research and extension activities are statewide and include development and conduct of harvest maturity management, postharvest handling, and storage technology from both basic and applied aspects. His current projects focus on the development of physiological disorders of apples such as internal browning, external carbon dioxide injury, and superficial scald.

- Doerflinger, F., Rickard, B., Nock, J. K., and Watkins, C. 2015. Early harvest is a critical factor in decreasing flesh browning development of Empire apples. *New York Fruit Quarterly* 23(3): 30–34.
- Gapper, N., Rudell, D., Giovannoni, J. J., and Watkins, C. B. 2013. Biomarker development for external CO₂ injury prediction in apples through exploration of both transcriptome and DNA methylation changes. *AoB Plants*. 2013: 10.1093/aobpla/plt021 .
- Watkins, C. B., and Nock, J. K. 2012. Production guide for storage of organic fruits and vegetables. http://www.nysipm.cornell.edu/organic_guide/stored_fruit_veg.pdf

Sustainable Apple Production and Cider Research (Greg Peck):

Greg is a new faculty member in Ithaca who comes to us from Virginia Tech and has a focus on sustainable orchards production systems and hard cider.

- Biggs, A. R., and Peck, G. M. 2015. Managing bitter pit in Honeycrisp apples grown in the mid-Atlantic United States with foliar-applied calcium chloride and some alternatives. *HortTech*. 25: 385–391.
- Farris, J., Peck, G., and Groover, G. E. 2013. Assessing the economic feasibility of growing specialized apple cultivars for sale to commercial hard cider producers. *Journal of Extension* 53(5) / 5FEA10.
- Thompson-Witrick, K. A., Goodrich, K. M., Neilson, A. P., Hurley, E. K., Peck, G. M., and Stewart, A. C. 2014. Characterization of the polyphenol composition of 20 cultivars of cider, processing, and dessert apples (*Malus x domestica* Borkh.) grown in Virginia. *Journal of Agricultural and Food Chemistry* 62(41): 10181–10191.

Orchard systems (Terence Robinson, currently on leave; and postdoctoral fellows, Poliana Francescato and Jaume Lordan Sanahuja):

Terence is an applied fruit crop physiologist, with a goal of doing practical research and extension on tree fruit production problems to increase the profitability and strength of the NY fruit industry and fruit growers around the world. His research and extension efforts are in: 1) Orchard Systems, 2) Rootstocks, 3) Crop Load and Canopy Management, and 4) Extension Leadership. His research and extension program is aimed at solving practical fruit production problems to increase the profitability and strength of the NY fruit industry. The program is largely field oriented and of an applied nature (Figure 3). Six areas of emphasis include: orchard systems, rootstocks, maximizing new tree growth, crop load and canopy management, irrigation/fertigation, and economics of orchard systems.

Poliana Francescato is studying the role and effectiveness of plant growth regulators. Jaume Lordan's research is focused on improving fruit tree orchard performance, selecting the right rootstock for each variety, and adapting their canopy management such as planting space, pruning, irrigation and crop load management techniques.

- Dominguez, L. I., and Robinson, T. L. 2015. Strategies to improve early growth and yield of tall spindle apple plantings. *New York Fruit Quarterly* 23(2): 5–10.
- Greene, D. W., Lakso, A. N., Robinson, T. L., and Schwallier, P. 2013. Development of a fruitlet growth model to predict thinner response on apples. *HortScience* 48(5): 584–587.



Figure 3. Terence Robinson during an orchard platform demonstration with Champlain Valley growers.

Plant physiology (Taryn Bauerle):

Taryn concentrates on perennial plants and has examined drought responses in apples.

- Bauerle, T. L., Centinari, M., and Bauerle, W. L. 2011. Shifts in xylem aperture and safety in grafted apple trees of differing growth potential in response to drought. *Planta* 234:1045–1054.

Apple Genomics (Kenong Xu):

Kenong and his group emphasize research and extension in tree fruit genomics. Their research goal is to uncover the genes underlying traits of economic importance in apple so that efficient tools and strategies can be developed for apple genetic improvement. The current research focus is on apple fruit quality and tree architecture traits, such as fruit acidity, storability, and columnar growth habit. They identified the fruit acidity gene, dubbed Ma, and developed a DNA marker capable of predicting fruit acidity levels at young seedling stages, making it useful for early selection in apple breeding. Extension program goals are to disseminate basic scientific information and information about the latest advances in plant biotechnology and genomics in layman's term for the fruit industry and other groups from the general public. This will enable a better understanding of genetically engineered crops and help the public to stay current with emerging biotechnology.

- El-Sharkawy, I., Liang, D., and Xu, K. 2015. Transcriptome analysis of an apple (*Malus x domestica*) yellow fruit somatic mutation identifies a gene network module highly associated with anthocyanin and epigenetic regulation. *Journal of Experimental Botany* 66(22): 7359–7376.
- Xu, K. 2014. Precision genome editing may ease debate and regulatory burden on genetically modified fruit. *New York Fruit Quarterly* 22(4): 29–32.

Plant Pathology and Plant Microbe Biology

Fruit Disease Resistance and Management (Kerik Cox):

Diseases severely compromise sustainable fruit production, and in the absence of sustainable host resistance and cultural management practices, growers need to rely on plant pharmaceuticals such as fungicides and bactericides. However, the safest and most effective fungicides and bactericides are overcome by development of resistance in pathogen populations. Therefore,

Kerik's research and extension program focuses on the identification, understanding, and mitigation of fungicide and bactericide resistance to promote a culture of pesticide stewardship in fruit production.

- Cox, K., Breth, D., Borejsza-Wysocka, E., and Aldwinckle, H. S. 2013. The presence of the fire blight bacterium *Erwinia amylovora* in asymptomatic apple bud wood: A potential threat to new apple plantings. *Phytopathology* 103(6): 31.
- Tancos, K. A., Villani, S. M., Kuehne, S., Borejsza-Wysocka, E., Breth, D., Carroll, J. E., Aldwinckle, H., and Cox, K. 2015. Prevalence of streptomycin-resistant *Erwinia amylovora* in New York Apple orchards. *Plant Disease* PDIS-09-15-0960-RE.

Virology (Marc Fuchs):

Marc's research and extension program focuses on the biology and management of viruses of vegetable and fruit crops. Primary research goals are to determine the variability of virus populations for advancing our understanding of virus spread, develop robust detection methodologies, and to study interactions between viruses, vectors, and plant hosts, with the aim of developing innovative plant protection approaches. His extension component focuses on the identification of emerging virus diseases and the dissemination of information to extension educators, growers, regulators, horticulture inspectors, and agriculture service providers.

- Gergerich, R. C., Welliver, R. A., Gettys, S., Osterbauer, N. K., Kamenidou, S., Martin, R. R., Gollino, D. A., Eastwell, K., Fuchs, M., Vidalakis, G., and Tzanetakis, I. E. 2015. Safeguarding fruit crops in the age of agricultural globalization. *Plant Disease* 99(2): 176–187.

Dave Gadoury:

David's research program focuses on discoveries that help protect a broad array of crops from microbes that cause diseases with a special emphasis on powdery mildews. His efforts led to breakthroughs in how important crops like apples, grapes, strawberries, wheat, and hops, are protected from attacks by powdery mildews in NY and beyond. David co-teaches a 2-credit undergraduate course, "Agricultural Application of Plant Health Concepts" (Figure 4).

Hudson Valley Research Lab, Inc.: Peter Jentsch (Director and Entomologist), Dave Rosenberger (PPMB Emeritus), Gemma Reig Cordoba (postdoctoral fellow and Horticulturist), and Dan Donahue (CCE) at the Hudson Valley Research Lab (HVRL) in Highland, NY, are dedicated to solving agricultural production problems, and emphasize communication of time-sensitive information to growers. Research programs focus on disease and insect pest management and horticultural production practices. <http://www.hudsonvalleyresearchlab.org/>

Entomology (Peter Jentsch):

The Jentsch Lab focuses on management of the beneficial and pest complex of insects and mites in tree fruits, small fruits, grapes and vegetable crops. Expertise includes field testing of experimental and conventional tools through integration of pest management of insects, employing biological controls and use of attractants to manage invasive pests in conventional and organic production systems. They study the woodland influence imposed on agricultural systems, coupled with a broadly diverse insect



Figure 4. Debbie Breth and Kerik Cox discussing apple diseases for students during a summer field course.

ecology and the warmer climate in Eastern New York's Hudson Valley region, which imposes significant pressure to agronomic systems unique in comparison with other regions of New York State, with studies that are specific and critical to region producers.

Extension activities include developing timely outreach materials on seasonal pest management events, participating in field and twilight meetings during the growing season, publishing extension articles for grower organization newsletters and bulletins, presenting through webinars, CCE sponsored fruit schools and workshops. Peter provides on-demand extension information using subscription based E-mail alerts linked to interactive 'blog site' articles containing recommendations and guidelines for management of timely IPM topics. This platform provides access to audio and video, and detailed images. Peter's blog is found at

<https://blogs.cornell.edu/jentsch/2016/01/>.

- Jentsch, P. 2015. A new threshold-based management tool for brown marmorated stinkbug (BMSB) in New York. *New York Fruit Quarterly* 23(3):19–23.
- Leskey, T.C., Agnello, A., Bergh, J. C., Dively, G. P., Hamilton, G. C., Jentsch, P., Khrimian, A., Krawczyk, G., Kuhar, T. P., Lee, D. H. and Morrison, W. R. 2015. Attraction of the invasive *Halyomorpha halys* (Hemiptera: Pentatomidae) to traps baited with semiochemical stimuli across the United States. *Environ. Entomol.* p.nvv049.

Plant Pathology (Dave Rosenberger): <http://blogs.cornell.edu/plantpathhv1/2016/01/>

Integrated Pest Management (<http://www.nysipm.cornell.edu/program/default.asp>) and the **Northeast Center for IPM** (<http://www.northeastipm.org/>):

Juliet Carroll (Senior Extension Associate, Fruit IPM Coordinator):

Julie educates farmers on using tools to grow healthy fruit crops with the fewest possible pesticide sprays. Lowering inputs while reducing the risk of crop loss from insects, disease and weeds also reduces the risk to human health and the environment. She delivers Cornell's knowledge about fruit to farmers at www.fruit.cornell.edu. Juliet's job is to learn from researchers, help with research, and deliver research knowledge to farmers for IPM—balancing farms, food and nature.

The Network for Environment and Weather Apps (NEWA) serves up open-access, user-friendly tools for farms at www.newa.cornell.edu. Juliet Carroll heads NEWA, now reaching across 16 states in the US. Forecasts on NEWA alert farmers about risk from damaging insects and deadly diseases so they can make smart decisions about monitoring, timing and protecting their crops. Farmers know the value of weather data is greater when it can be shared. NEWA makes it possible for farmers to share weather station data—building tools for farm decision support. <http://newa.cornell.edu/> and the You're NEWA blog is at <http://blogs.cornell.edu/yournewa/>

The Dyson School of Applied Economics and Management (Brad Rickard):

Brad's teaching and research focus on the economic implications of policies, innovation, and industry-led initiatives in food and beverage markets. His extension program is tied to his research, and focuses on answering economic, marketing, and policy questions important to horticultural producers, particularly fruit and vegetable growers, in New York State. As part of his extension program, he works with researchers across units in the College of Agriculture and Life Sciences to study issues in a multi-disciplinary framework.

- Rickard, B. J., Richards, T., and Yan, J. 2016. University licensing of patents for varietal innovations in agriculture. *Agricultural Economics* 47: 3–14.
- Rickard, B. J. 2015. On the political economy of guest worker programs in agriculture. *Food Policy* 52: 1–8.

Food Marketing and Distribution (Miguel Gómez):

Miguel's research program concentrates on two interrelated areas under the umbrella of food marketing and distribution: 1) Supply chains competitiveness and sustainability, and 2) Retailing and channel relationships. Here, microeconomic theory is combined with quantitative methods, emphasizing key concepts such as price transmission, demand response, buyer-seller negotiations, market power, customer satisfaction, and retail performance.

- Gómez, M., McLaughlin, E. W., and Park, K. S. 2014. Case studies on local food supply chains: Apple case studies in the Syracuse, New York MSA. In: King, R. P., M. Hand, and M. I. Gómez (Eds.), *Comparing the structure, size, and performance of local and mainstream food supply chains*. Univ. Nebraska Press.

Agribusiness Management and Ag Economic Development (Todd Shmidt):

Cornell University Food and Brand Lab (Brian Wansink, David Just and others, at

<http://foodpsychology.cornell.edu/>):

The Food and Brand Lab is an interdisciplinary group of graduate and undergraduate students from psychology, food science, marketing, agricultural economics, human nutrition, education, history, library science, and journalism, along with a number of affiliated faculty. It focuses on better understanding consumers and how they relate to foods and packaged foods. Their research has driven the creation of the Smarter Lunchrooms Movement [<http://smarterlunchrooms.org/>] and the Cornell Center for Behavioral Economics in Child Nutrition Programs (BEN) [<http://ben.cornell.edu/>], two programs devoted to the

funding, conduction, and dissemination of research concerning children's health. A few of their studies on apples include:

- Just, D. R., Hanks, A. S., and Wansink, B. 2014. Chefs move to schools: A pilot examination of how chef-created dishes can increase school lunch participation and fruit and vegetable intake. *Appetite* 83: 242–247.
- Tal, A., and Wansink, B. 2015. An Apple a Day Brings More Apples Your Way: Healthy Samples Prime Healthier Choices. *Psychology and Marketing* 32(5): 575–584.
- Wansink, B., Just, D. R., Hanks, A. S., and Smith, L. E. 2013. Pre-sliced fruit in school cafeterias: Children's selection and intake. *American Journal of Preventive Medicine* 44(5): 477–480.

USDA ARS Plant Genetic Resources Unit:

The USDA PGRU maintains one of the world's largest collections of apple germplasm (trees, cryopreserved buds, and seeds), including collections from the center of origin in apple (in China and Russia). The facility has over 3,900 apple accessions and is often referred to as a living library. USDA apple researchers with adjunct faculty status at Cornell include Gan Yuan Zhong (research leader), Thomas Chao (curator) and Gennaro Fazio (rootstock breeder).

- Volk, G. M., Chao, C. T., Norelli, J., Brown, S. K., Fazio, G., Peace, C., McFerson, J., Zhong, G.-Y., and Bretting, P. 2015. The vulnerability of US apple (*Malus*) genetic resources. *Genetic Resources and Crop Evolution* 62(5): 765–794.

Apple Rootstock Breeding (Gennaro Fazio):

This is a collaborative program between the USDA and Cornell University. The focus in this program has been to develop size-reducing rootstocks that also have resistance to replant disease, *Phytophthora* root rot, woolly apple aphid, scab, and fire blight (Figure 5). Information on the rootstocks commercialized and their attributes is at <http://www.ctl.cornell.edu/plants/GENEVA-Apple-Rootstocks-Comparison-Chart.pdf>. Gennaro's research has indicated the importance of rootstock on apple mineral nutrition and has identified genes involved in apple dwarfing.

- Fazio, G., Cheng, L., Grusak, M. A., and Robinson, T. L. 2015. Apple rootstocks influence mineral nutrient concentration of leaves and fruits. *New York Fruit Quarterly* 23(2): 11–15.
- Robinson, T., Fazio, G., Black, B., and Parra, R. 2015. 2015 Progress report – Evaluation of the Cornell-Geneva apple rootstocks and other promising apple rootstocks. *Compact Fruit Tree* 48(1): 22–25.

Other Faculty investigating aspects of apple:

Joss Rose, a specialist in fruit skin (cuticles), is studying the cuticle of apples to understand apple surface defects associated with cuticle formation, such as russeting, wind-whip and weather-cracking.

Retirees who have contributed to apple research include (in CCE): Allison DeMarree, Steve Hoying, Kevin Iungerman, Mike Fargione and (faculty): Alan Lakso, Ian Merwin, Harvey Reissig, and Dave Rosenberger. We are sure this list is incomplete, so our apologies if you were missed!



Figure 5. Geneva apple rootstocks being grown in a commercial nursery (photo: Gennaro Fazio)

- Merwin, I. A. 2015. Growing apples for craft ciders. *New York Fruit Quarterly* 23(1): 5–9.

Web and Print Resources:

- **The Cornell Fruit website** www.fruit.cornell.edu/ contains links to Scaffolds Fruit Journal, IPM, CCE, organic guides, the New York Fruit Quarterly, and many other links.
- **Scaffolds Fruit Journal**, a weekly update on pest management and crop development is available at <http://www.scaffolds.entomology.cornell.edu/>.
- **The New York Fruit Quarterly** is printed 4 times a year and is a joint effort of the New York State Horticultural Society, Cornell University's New York State Agricultural Experiment Station at Geneva, and the New York State Apple Research and Development Program. Michigan researchers also contribute reports. <http://www.nyshs.org/fq.php>.
- **2016 Cornell Pest Management Guidelines for Commercial Tree Fruit Production:** <https://store.cornell.edu/p-193115-2016-cornell-pest-management-guidelines-for-commercial-tree-fruit-production.aspx>.
- **The Apple Research and development Program (ARDP)** was established by the NY apple industry in 1990 in New York. In 2012, the ARDP voted to double research funding from just under \$200,000 to nearly \$400,00 per year. In 2014, it was successful in getting a \$500,000 match from the NYS legislature and the Cuomo administration. Many articles in the New York Fruit Quarterly represent projects funded by ARDP.

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