Accomplishments Report, 2016 NC 140 Project

Impact Nuggets

- Sweet cherry performance has varied widely by site and scion cultivar in on-going coordinated trials examining diverse canopy architectures matched with rootstocks of varying vigor levels. Some radical canopy architectures are proving to be both yield-efficient and labor-efficient.

- Stooling or layering beds are still the main method for propagation of apple rootstocks. Research performed at Geneva to improve rooting of Geneva rootstocks has resulted in the application prohexadione calcium sprays by several U.S. nurseries. In addition, commercial stool beds established by planting tissue culture material in a double row configuration have increased productivity of new beds and quality of liners available to the industry. A significant portion of apple rootstocks in 2016 was produced with in-vitro methods and by cuttings. While more expensive than propagation beds, these methods induced more primary roots and increased transplant survival and vigor.

- In a collaborative project including Utah State University, Cornell and USDA, researchers found that some apple scions with G.41 rootstock form brittle graft unions, regardless of grafting method. The brittleness is associated with high rigidity, but is not associated with any detectable change in hydraulic resistance across the union. BA applications directly to the graft union increased break strength. Apogee similarly increased strength, but also reduced scion growth

- For stone fruit, Controller 9 and Controller 6 rootstocks are receiving increased attention for peach and nectarine plantings in California. Several large acreage plots have been planted and nurseries are having difficulty satisfying the demand for trees. There is increased interest in growing "pedestrian" orchards that can be managed without ladders.

New Facilities and Equipment

A new house was constructed for graduate students and visiting scientists at the Fruit Research and Education Center, Biglerville, PA, with funding ($250,000) from the State Horticultural Society of Pennsylvania. The University of Maine purchased a FLIR E5 infrared camera, ΔA Meter, Truroni Campbell weather station instruments for relative humidity, air temperature, soil temperature and soil moisture for apple rootstock research. In Michigan, orchard covering systems were tested to protect high density sweet cherry trees from frost, rain, wind, hail, birds, and some diseases. An over-the-row mechanical harvester was tested for high density tart cherry production. Battery-powered handheld pruners and hedgers were used to impose dormant and summer pruning treatments in cherries. Approximately two acres of orchard was established in 2016 at the University of Guelph, Simcoe Research Station. This included a new peach rootstock experiment, a new hard cider orchard, and orchard for future plant physiology research. In Utah a GPS-based trailer mounted ceptometer has been assembled for mapping light interception in tart

cherry orchards. This will be used to compare pruning and training strategies in both conventional and high density plantings.

Unique Project Related Findings

On the alkaline soils of Utah, peach trees on Krymsk1, Krymsk 86, Mirobac, Br. Hybrid 5 and Penta had greener leaves than trees on Lovell. Of the 16 peach rootstocks in a Georgia trial, only Guardian and Controller 8 have no tree mortality. In Illinois and Massachusetts, *Prunus Americana* had very high numbers of root suckers. In Missouri, peach trees on the plum rootstock, Penta, bloomed earlier than trees on the other rootstocks. In South Carolina Rootpac 20 (Densipac) and Rootpac 40 (Nanopac), from the Spanish Company Agromillora Iberica, were planted in 2 locations and after 3 years, trees are dying due to *Pseudomonas syringae*.
In an apple demonstration trial planted in northern Maine (zone 3) in 2014, trees on G.30, G.11, G.202 and V.1 lacked sufficient hardiness to survive early spring freezing temperatures (-29 C). In Michigan 'Honeycrisp' trees on PiAu51-1, B.70-20-20 and B.70-20-21 had the most bitterpit, whereas trees on G.935, G.4003, G.214 and B.9 had low levels of bitterpit. In Minnesota, 'Honeycrisp' yields were negatively related to the severity of zonal chlorosis, but trees on CG.5067 had high chlorosis and high yield. In New York, trees of the nonvigorous cultivar 'SnapDragon' CG.5257 had the highest yields and also had a spreading growth habit.
Five new dwarfing rootstocks from the Michigan cherry rootstock program are being propagated for the 2017 NC140 coordinated trial. In British Columbia, the UFO training system for sweet cherry had the highest yield and renewal pruning and spur pruning have been used to balance tree vigor and maintain fruit size. In New York, pear yields were negatively related to tree spacing and trees on OHxF69 planted at 3' between trees and trained as Tall Spindle had the highest yields. In California, Horner-4 pear rootstock has performed uniquely well. Despite its vigor and resulting potential size it is very precocious and productive and it is being tested under a wider range of conditions, such as heavier, wetter soils.

Accomplishment Summaries

Objective 1. To evaluate the influence of rootstocks on temperate-zone fruit tree characteristics grown under varying environments using sustainable management systems.

Projects in various stages of data collection, evaluation and planning include the following in association with years of plot establishment and identification of trial coordinators:

2009/2014 Peach Physiology (Rich Marini)
2009 Peach Rootstock (Greg Reighard)
2010 Apple Rootstock (Wes Autio)
2010 Sweet Cherry Rootstock and Training Systems (Greg Lang)
2013 Pear Training/Rootstock/Spacing (Todd Einhorn)
2014 Apple Rootstock (John Cline)
2015 Organic Apple Rootstock (Terence Robinson)

2017 peach rootstock Trial (Greg Reighard)
2017 Sweet cherry Rootstock trial (Greg lang)
2017 Tart cherry Rootstock Trial (Greg Lang)
2018 Apple Rootstock Trial (Stephano Musacchi)
2018 Apricot Rootstock Trial (Gregg Lang)
2019 Pear Rootstock Trial (Todd Einhorn)

Future plantings for all crops for 2018 and beyond, are in various stages of planning at this time.

Apple Sub-Committee (Chair, Stefano Mussachi, WA)

The 2010 Apple Rootstock trial was established at 13 locations with Honeycrisp and six locations with Fuji. It includes 28 Budagovsky, Cornell-Geneva, and Pillnitz rootstocks and three commercial controls. After seven growing seasons, largest trees were on B.70-20-20 and B.64-194; the smallest were on B.71-7-22. Greatest cumulative yield were from trees on CG.4004; the least from trees on B.71-7-22 (Honeycrisp) and B.67-5-32 (Fuji). Most cumulatively yield efficient trees were on G.11 and G.4003 for Honeycrisp and on B.9, G.935N, and CG.5087 for Fuji. The largest fruit on average were from trees on B.64-194 for Honeycrisp and from trees on G.41N for Fuji. Trees on PiAu 9-90 had the highest chlorosis in BC and trees on B.73-150 had the lowest chlorosis. The 2014 Apple rootstock planting was established in 15 locations in the United States (AL, ID, IN, MA, ME, MI, MN, GA, NJ, NY, PA, UT, VA, WA, WI), two in Canada, and one in Mexico (http://bit.ly/1zv3wCc). The trial consists of the following rootstocks: B.10, G.11, G.202, G.214, G.30, G.41, G.5890, G.935, G.969, M.26 EMLA, M.9 T337, V.1, V.5, V.6, V.7. The trial is being coordinated by John Cline who has also agreed to analyze the data. This trial has two cultivars: Aztec Fuji (AL, ID, GA, NJ, ON, PA, UT) and Honeycrisp (ID, IN, MA, ME, Mexico, MI, MN, NJ, NY, Ontario, PA, VA, WA, WI), planted to a 'tall spindle' systems at a 5 x 12 feet, and 4 x12 feet spacing, respectively. Trees are planted using a randomized block design with single trees serving as experimental units. Each site selected a pollinizer variety since some sites are very limited in adapted varieties. Trees were established in the spring of 2014. The trees were propagated by Willow Drive Nursery, WA. Data protocols have been established for 2014 and 2015. This is a young trial with no significant findings being reported at this time. The 2015 Organic Apple Rootstock Trial, was established in 2015 in 13 US and 1 Mexican state and will evaluate 9 Geneva rootstocks and M.9 NAKBT337 as a control. All trees are managed organically and trained as Tall Spindles. Modi is the cultivar and Liberty is the pollinizer. The design is five blocks in two-tree sets and will require 1/10 acre. Organic certification is optional, but orchard management must be organic. After two seasons, trees on G.41 and G.202 had larger trunks than trees on G.16 and G.222.

Cherry Sub-Committee (Chair, Greg Lang, MI)

The 2010 Sweet Cherry Rootstock x Canopy Training System Coordinated Trial began with 13 sites; these have diminished to 5 due to diseases, cooperator retirements or transitions, deer damage, etc. Sweet cherry performance has varied widely by site and scion cultivar in on-going coordinated trials examining diverse canopy architectures matched with rootstocks of varying vigor levels. Work has begun on the first trial paper (Training Systems Establishment, Years 1-4)

with adequate data expected from CA, MI, NY-Geneva, NY-New Paltz, NS, and BC. Since most training systems under test are new and novel, information about proper training and pruning is being developed respect to tree spacing and the range of rootstock vigor in the trial – in some system x rootstock combinations, excessive shading may be causing yields to diminish. The focus of canopy management is to optimize light distribution and minimize shade, promote balanced cropping and renew the structural fruiting sites. Gi3 combined with Upright Fruiting Offshoots system was insufficiently vigorous for 1.5 x 4 m spacing in British Columbia. Conversely, trees on Gi6 trained to the SSA system in Michigan has been overly vigorous at 0.75 m x 3.5 m. Two 2010 Tart Cherry Rootstock x Canopy Training System Independent Trials were established in UT and MI. The focus is on examining rootstock x canopy training interactions to develop hedgerow-type trees for over-the-row mechanical harvest. Trees were mechanically harvested in 2016. The 2017 Sweet Cherry Rootstock trial, coordinated by Greg Lang (MI), will have 5 Michigan State rootstocks, 3 Gisela stocks (3, 5, 12), Krymsk 6, and MxM14. Trial sites include OR, CA, WA, ID, MI, NY, and BC with Benton as a scion. Trees will be trained as 2 or 3 systems at each site. MSU-developed cherry rootstock selections exhibit vigor reduction and precocity comparable to Gisela 3 and Gisela 5 rootstocks for tart and sweet cherry scion varieties in preliminary trials in WA and MI. Preparations have begun to include these in 2017 NC140 coordinated comparative trials for high density sweet and tart cherry production.

Pear Sub-Committee (Chairs, Todd Einhorn, OR; Rachel Elkins, CA)

The 2005 pear Rootstock Trial was terminated in 2014 and results were published in ACTA Hort. However the trees in California are being used for crop load adjustment experiments and only trees on 708-36 and Pyrodwarf had larger fruit following fruit thinning after June drop.The 2013 pear training/rootstock/spacing trial coordinated by Todd Einhorn was designed to evaluate the main effects and interactions among rootstock (OH×F 87, OH×F 69 and Pyro 2-33), training system (single axe V, single axe tall spindle, bi-axe vertical), and intra-row spacing (3, 4.5 and 6 ft.) on pear production. Cooperators are OR (Anjou), NY (Bosc), and CA (Bartlett). Across all sites, trees were smallest on Pyro 2-33. For Bartlett and Bosc, trees on OHxF87 were smaller than on OHxF69. Trunks of bi-ais trees were half the size of single axis trees. For Anjou, but not the other cultivars, tree size was positively related to in-row spacing. Yields of fourth-leaf trees were low at all sites (0.8 kg/tree) and not consistently affected by the any one of the factors evaluated. T. Einhorn is coordinating a 2018 rootstock trial to evaluate dwarfing potential and productivity of cold-hardy quince accessions on pear. Cooperators include OR, Nova Scotia, NY, PA, and WA. Ten to 14 genotypes presently in tissue culture will be propagated in 2016 and delivered to a nursery for propagation. Rootstocks will be budded to select scions, with and without interstems. OH×F 87 will serve as the control.

Peach Sub-Committee (Chairs, Greg Reighard, SC; Rich Marini, PA)

The first five years of data for the 2009 peach Rootstock Trial were summarized and a draft of a manuscript will be completed in January 2017. After seven years, 13 sites remain in the trial. Tree survival was highest for peach seedling rootstocks at all lcoations, whereas survival of non-

peach species and hybrid rootstocks was poor to fair at five locations. Imperial California had the lowest survival. Prunus Americana seedlings produced large numbers of root suckers.

Largest trees were three *Prunus* x almond hybrids and Guardian®. Fruit size varied with location and crop load (i.e., some rootstocks had few fruit). KV010127 produced the largest fruit and Controller 5 and Mirobac (a.k.a Replantpac) the smallest fruit across all sites. Cumulative yields were generally highest with the peach rootstocks, especially Guardian®. Lowest yields were from plum hybrids and species. Cumulative yield efficiency was highest on the non-peach rootstocks including many of the plum hybrids or species. However, many of these rootstocks produced trees much smaller than the peach and almond hybrid cultivars. These data suggest there were no advantages to using clonal interspecific *Prunus* hybrids for peach production under current cultural practices. The clonal *P. persica* rootstocks 'Controller 8' and 'Controller 7' are the most promising of the size-controlling rootstocks tested. The 2009 Peach Physiology Trial is focusing on the interactive effects of early-season temperature, cultivar and crop density on average fruit weight. Five cooperators (NY, ID, MD, SC, and KY). Trees were thinned early in the season to develop a range of crop densities and days from bloom to harvest, average fruit weight and growing degree days. At a given crop density, Cresthaven fruit weight was lower for KY and NY than for MD, SC and ID. For Redhaven, fruit weight was related linearly to crop density and curvilinearly to growing degree days. An additional year of data is needed to develop models.

Objective 2. To develop improved rootstocks for temperate-zone fruit trees using state-of-the-art genomic tools in breeding programs.

A new breeding program was initiated in June 2015 at Washington State University to develop dwarfing precocious pear rootstocks. A cherry rootstock selection program (based on sour cherry scion breeding efforts) at MI has identified 5 elite genotypes, Cass, Clare, Lake, Crawford, and Clinton, that confer significant vigor control, precocity, and high productivity to sweet and tart cherry scions. These are being propagated for a 2017 NC140 coordinated trial evaluation as well as trials with selected scientists and growers. In 2016, the apple rootstock breeding program at Geneva, N.Y. released G.213 rootstock in Brazil and the U.S. This rootstock produces a tree similar in size to M.9 Nic29 with good yield efficiency, resistance to fire blight and wooly apple aphids and some tolerance to replant disease. In Brazil this rootstock increases bud break in low chill environments. In the nursery it induces more feathers that other commercial rootstocks. In the stool bed the shanks are straight but may possess some spines if the bed receives too much fertilizer and has not been planted in high density. As part of the recently funded Root 2 Fruit SCRI project, NC140 members are initiating research involving DNA sequencing to evaluate rootstocks for nutrient uptake capacity and tolerance to biotic stresses. The second year of a multistate/agency genomics project to genotype the entire NCGR Corvallis pear germplasm collection was completed. The effort is detailed at *http://ucanr.edu/sites/peargenomics/*. PGRN members collaborated on a multistate/agency (UC, WSU, OSU, USDA Kearneysville, USDA-NCGR Corvallis) SCRI pre-proposal to coordinate and develop a pear rootstock improvement program (submitted November 2016). Target traits are size control, fire blight and *Armillaria* resistance, and iron chlorosis.

Objective 3. To accelerate adoption of new rootstocks (a) by improving propagation

techniques and (b) by acquiring new rootstocks from worldwide sources.

Discussions, led by MI, are on-going to assist in the importation and propagation of several cherry rootstocks (Gi13 and Gi17), from Germany known as the WeiGi series as well as potential apricot rootstocks. These stocks will be tested in future NC 140 cherry rootstock trials. Three Amelanchier rootstock genotypes were developed from intra- and interspecific hybridization (Germany) and tested in two plantings in Hood River, OR using 'D'Anjou' as the scion and compared to OH×F 87. Trees were established in a rootstock trial in OR on Amelanchier, which have been found to be are highly dwarfed (i.e., half the size of those on OH×F 87). Amelanchier rootstocks conferred high productivity to 'D'Anjou' resulting in ~60 flower clusters and 20 fruits per tree, a 6- and 10-fold increase over OH×F 87 for these factors, respectively. Some of the When brittle apple cultivars are budded onto some of the Geneva rootstocks, nurseries and orchardists have lost trees to breakage at the union. Using laser ablation tomography PA researchers found that weak and strong combinations both contained areas of poor xylem differentiation at the graft union. Researchers in UT found that application of plant growth regulators to the graft union of nursery trees increased break strength of trees.

Objective 4. To better understand the impacts of biotic and abiotic stresses on scion/rootstock combinations in temperate-zone fruit trees.

Biotic stresses. Tree nutrition influences tree growth and fruit quality. Bitter pit severity of HomeyCrisp was recorded at by several locations. At MN bitter pit was severe, but was not influenced by rootstock. In MI trees on G.41 had the greatest bitter pit, whereas trees on V.1, and M.9T337 had little bitter pit. In ID trees on B.20-20-21, G.11 and CG.5087 had high leaf N, whereas trees on B.64-194 and B.70-20-20 had high leaf K. Bitter pit will be evaluated by more collaborators in 2017. The majority of trees on *P. persica,* but not *Prunus* hybrids and other *Prunus* species of rootstocks, survived in GA. In the Sandhills region of NC, fumigation is strongly encouraged to minimize the potential for peach tree short life, even when Guardian is used. *Prunus* rootstocks that had *P. dulcis* or *P. domestica* in their lineage survived poorly in SC, but no rootstocks of 100% *P. persica* have died. Soil fumigation may be beneficial for apple trees planted in replant sites in NC or the best alternative would be to use alternative rootstocks, such as G.30 or G.210 rather than M.7 in replant sites. In the spring of 2015, 12 plants of two scion varieties, Honeycrisp and Gala, were grafted onto 4 rootstocks (G890, G41, Bud-9 and M9-T337) and grown in the greenhouse to study uptake of calcium and nitrogen in WA. Isotope tracers, whole plant mass balance uptake and distribution models will be combined with metabolomics and genomic profiling.

Abiotic stresses. In British Columbia, cherry rootstocks and training systems had little effect on stomatal conductance, but Gi3 and Gi5 had lower midday stem water potential than Gi6 trees on four of eight sampling dates. Gi3 was more susceptible to colonization with root lesion nematodes than Gi5 and Gi6 trees. No bacterial canker was observed. In Nova Scotia, water relations were assessed in both 2010 Honeycrisp and 2010 Sweet Cherry rootstock trials. Sweet cherry showed water stress initially and 3 weeks prior to harvest; Gi3 had higher values than Gi5 and Gi6. At the start of harvest TSA trees were more water stressed than UFO trees. Following harvest, when rainfall was well below the monthly average for August and September, Gi3 was most water

stressed. Honeycrisp trees were measured 10 weeks before harvest and into the harvest season. HoneyCrisp water relation were affected little by rootstock in 2016

Objective 5. To enhance the sustainability of temperate fruit farming through development and distribution of research-based information utilizing eXtension.

The NC-140 web site, http://nc140.org continues to be our primary outreach component serving as an important collaboration tool for cooperators. Members of the research group communicate through a list serve, and upload/download project files to password-protected directories (NJ, MA). We have used the site to allow for easier collaboration and comparison of replicated rootstock trials. Requirements for web page design for regional projects have been met as outlined by the NIMMS and the North Central Regional Association of Agricultural Experiment Station Directors (NCRA). Articles, photographs and reports were archived throughout the year. Members of our research group have continued to make research-based information available to anyone who would like to use it through eXtension (MN, PA, MA, NY, NC, MO, OH, WV, IN, VA). eXtension is not used in Canada . The database has been completed for apple rootstocks and cultivars and can be viewed at http://www.extension.org/apples. This project was funded through the USDA-SCRI program and was completed in August 2014. We have linked to the primary website for the research group, www.nc140.org. For 2016 eApples content constituted 1.1% of all views on eXtension. NC-140 also maintains its own Email distribution list for internal communication. The posting Email address is nc140@virtualorchard.net. Reports, presentations, and videos that update NC140 cherry, apple, and stone fruit rootstock research and extension at MI are regularly posted on www.cherries.msu.edu, www.apples.msu.edu, www.hrt.msu.edu/greg-lang, and www.giselacherry.com. These have been cited by fruit growers throughout the United States around the world as valuable sources of information for new orchard planning and production. The Penn State Tree Fruit Website was upgraded with the addition of several posts on cultural practices including information on apple rootstocks, apple cultivars, training systems, calcium nutrient management and Honeycrisp management.

Impact Statements

Fruit yield, quality and labor efficiencies in Michigan high density sweet and tart cherry production systems are stimulating grower experimentation with these new canopy training concepts. Such canopy architectures better facilitate protective orchard covering and climate modification technologies that result in more consistent sweet cherry production and lower pesticide use.

In Nova Scotia, the local packing plant and apple producer COOP, Scotian Gold Ltd., toured the NC-140 Honeycrisp orchard in September and is using the results to plan future plantings in Nova Scotia. Cherry producers have expressed interest in the dwarfing cherry rootstocks and the training systems for U-pick potential.

In Massachusetts, 200 acres of trees on dwarfing rootstock were planted in 2016 based on results of NC-140. On this acreage, pruning and harvest labor declined by 50%, fruit quality and size increased by 20%, profit increased by 50%, and because of reduced canopy volume, pesticide use declined by 70%.

The California NC-140 peach and pear trials have resulted in new commercial trial plantings of tested rootstocks, as well as support for high density systems trials which will influence future research plantings.

In Maine during the past five years, 200 acres of apple trees planted on dwarfing rootstocks were based on research results from NC-140.

The uniform apple rootstock trials in MN and ME have allowed growers in USDA hardiness zones 3 and 4 to evaluate new rootstocks for planting in commercial and home orchards.

Research performed by NC-140 provided the foundation for the newly funded SCRI project "Roots 2 Fruit". Most collaborators in this new project are also NC-140 members and some of the existing NC-140 plantings will be used for various aspects of the new project.

Other Relevant Accomplishments and Activities

The NC 140 project was awarded the Experiment Station Section Award for Excellence in Multistate Research in 2015. The award was officially presented at the annual Association of Public and Land Grant Universities annual meeting November 14, 2015. The award recognized this regional project's contributions for over 40 years to the fruit growers in North America. NC 140 has been critical to the steady transition to higher density orchards, which has benefited consumers with higher quality fruit at reasonable prices. http://agisamerica.org/september-2015-land-grant-institutions-work-across-state-lines-to-increase-fruit-tree-production/. The project was given a $15,000 stipend to go towards project improvements and scholastic endeavors. The majority of the stipend will be used to provide scholarships to graduate students to attend the 2017 NC-140 meeting in North Carolina and make short research presentations. This is an important activity to train the next generation of pomologists by providing an opportunity for graduate students to learn about multi-state projects, specifically the NC-140, and to tour research plantings.