Multistate Research Activity Accomplishments Report
Project Number: NC-140
Project Title: Economic and Environmental Sustainability and Fruit Tree Production Through Changes in Rootstock Use
Period Covered: Oct. 1, 2007-Sep. 30, 2008
Date of This Report: January ,2009
Annual Meeting Dates: November 15-18, 2008

Participants: See annual meeting minutes, available on the NC-140 web-site: http://www.nc140.org. The project's email distribution list is maintained by W. Cowgill, (NJ) and J. Clements, (MA). The posting e-mail address is nc140@virtualorchard.net.

Summary of Minutes: See annual meeting minutes, available on the NC-140 web-site: http://www.nc140.org.

Accomplishments and Impacts:
Objective 1. To evaluate the influence of rootstocks on temperate-zone fruit trees characteristics grown under different management systems and environmental conditions.

Several multi-state coordinated trials were concluded in late 2007 or in 2008, and data from these plantings have either been published or are being prepared for publication. These include:

- 1999 Dwarf and Semi-dwarf Fuji/McIntosh apple rootstock trial which compares 21 apple rootstocks at 17 locations in North America. The final report is in preparation and will be submitted for publication in the J. Amer. Pom. Soc. in 2009.
- 2001 Peach trial of 14 *Prunus* rootstocks. A paper was submitted to ISHS in 2008. The final report is near completion, and will be submitted for publication in the J. Amer. Pom. Soc. in 2009. The report will include a data table summarizing each site, making it more readily accessible to fruit growers. Bailey was the most yield-efficient rootstock across the sites, and Controller 5 was the best of the California rootstocks.
- 2002 Peach trial of three peach varieties on eight roostocks. The final report is near completion and will be submitted for publication in the J. Amer. Pom. Soc. in early 2009.
- 2002 Cresthaven peach physiology trial, comparing the effect of location in North America on harvest date, fruit weight, and soluble solids content. A paper was submitted to ISHS in 2008. The final report is in preparation and will be submitted for publication in the J. Amer. Pom. Soc. in 2009.

Numerous projects are still ongoing. These include:

- 2002 Gala apple rootstock trial compares 20 apple rootstocks at 10 locations in North America. A 5-year report was published in the Journal of the American Pomological Society.
- 2002 Cameo apple rootstock trial compares 3 rootstocks at 2 locations in the eastern USA. A five year report abstract was published in 2008.
- 2002 Pear rootstock trial compares 7 rootstocks at 4 locations in the North America. A gap in leadership for this trial has postponed publication of a 5-year progress report. A report is being prepared and will be submitted for publication in 2009.
- 2003 Golden Delicious apple rootstock and physiology trials compares 23 rootstocks at 14 locations. A progress report is in preparation and will be submitted for publication in 2009.
- 2004 Pear rootstock trial compares 3 rootstocks at 3 locations in North America. A 5-year report will be submitted for publication in 2009.
- 2005 Pear rootstock trial compares 7 rootstocks with Bartlett and 3 rootstocks with Bosc.
- 2006 Gala apple replant trial compares 12 rootstocks at 10 locations in fumigated and unfumigated soil at each site.
- 2006 Cherry physiology trial compares the yield and fruit size of a dwarfing cherry rootstock at 4 locations in North America.

Objective 2. To develop and improve rootstocks for temperate-zone fruit trees with breeding and genetic engineering, to improve propagation techniques for rootstocks, and to acquire new rootstocks from worldwide sources.

- Development of new rootstocks: New York State, in cooperation with the USDA continues to develop and test new rootstocks. Two tests with Honeycrisp and Fuji are helping to identify new elite clones. It is expected that four new semi-dwarfing rootstocks will be released in 2009.
- Propagation of apple rootstocks: New York State, in cooperation with the USDA continues to work on techniques to improve propagation of apple rootstocks – primarily difficult-to-root Geneva rootstocks such as G41. These include planting density, plant orientation, tissue culture, early-season shading, and growth regulators. Results of these experiments will be summarized in 2009.

Objective 3. To study the genetics and developmental physiology of rootstock/scion interactions in temperate-zone fruit trees.

- In NY, a joint trial is being done on the mapping of root architecture traits on the genome. A population of unscreened seedling is being evaluated for root morphological characters which will allow mapping of root architecture characteristics.

- An ongoing breeding program in Arkansas is testing twelve new apple and 44 new peach rootstock selections. A breeding program in Michigan has developed a new series of tart cherry rootstocks which will be evaluated in the next NC-140 cherry rootstock trial. Breeding programs in California and Georgia are developing new peach rootstocks.

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

- Apple rootstock tolerance to soil pH is being evaluated in NY. A field trial in pots of Golden Delicious on 30 Geneva rootstocks is being conducted for tolerance to low and high soil pH. This trial began in spring, 2008. Tree growth and root growth will be evaluated in 2010.
- Apple rootstock tolerance to replant disease is being evaluated in NY. A field trial in pots of Golden Delicious on 30 Geneva rootstocks is being conducted for tolerance to replant disease in both sandy and clay soils. This trial began in spring, 2008. Tree growth and root growth will be evaluated in 2009.
- Cold Hardiness Testing of New Apple Rootstocks continues in ME. G.5935 had greater root tissue cold hardiness than M.26 EMLA, based on shoot growth following exposure to freezing temperatures to a low of -16 °C. Changes in rootstock selection can increase yield and tree survival leading to greater profitability. Knowledge of correct tree spacing can prevent economic losses. Impacts will be measured as changes in the industry and will be documented through grower surveys.

Work Planned for Next Year

Existing plantings will be maintained and data collection will continue according to protocols developed by the respective technical committees. Planting coordinators will analyze and summarize data from the various sites for each coordinated planting, and will lead in writing 5-year progress reports and 10-year final reports for publication. Technical sub-committees for 4 fruit commodities (apple, cherry, peach, and pear) have developed plans for future multi-state coordinated plantings which will support project objectives.

Apple Sub-Committee (T. Robinson, Chair) Plans were finalized to proceed with a multi-state apple rootstock trial to be planted in 2010. The trial will consist of 31 rootstocks, including new Russian and Geneva rootstocks, with Honeycrisp and Fuji as the scions. The trial will be planted at 21 locations in North America. T. Robinson (NY) will organize the trial and W. Autio (MA) will coordinate the data.

Cherry Sub-Committee (G. Lang, Chair) Plans were developed for a high-density sweet cherry trial to be planted in 2010. This trial will evaluate three dwarfing rootstocks and three training systems. The trial will be planted in WA, MI, OR, NY, and NS, with cultivars differing by state. Plans were also developed for two independent 2010 plantings of high-density tart cherries in UT and MI for mechanical harvest. The UT trial will evaluate three rootstocks at multiple row spacings with Montmorency as the scion. The MI trial will evaluate four rootstocks and own-

rooted Montmorency with three training systems. G. Lang (MI) will organize the trials and coordinate the data. Plans were initiated for a new rootstock trial to be planted in 2011 or 2012. A coordinator for this trial has not yet been identified.

Peach Sub-Committee (G. Reighard, Chair) Plans were finalized for the 2009 trial of 15 rootstocks with Redhaven as the scion. Currently there will be 14 planting locations throughout North America, and 3 more are interested in participating. A limited number of trees may limit the number of planting locations. Plans were also finalized for the 2009 physiology trial. G. Reighard (SC) will organize the trial and coordinate the data.

Pear Sub-Committee (R. Elkins, Chair) New quince materials from Poland are being evaluated for relative cold-hardiness to be used in 2011 high-density planting. Plans were developed for a 2012 planting using new rootstocks from the Horner series. New rootstocks from France and England may also be included. R. Elkins (CA) and S. Castagnoli (OR) will organize the trials and coordinate the data. Plans were initiated for a multi-state asian pear cultivar trial. A coordinator for this trial has not yet been identified.

Plum Sub-Committee (T. Robinson, Chair) Data is being gathered, and a draft of the last planting is being prepared.

SCRI Committee A committee was appointed to pursue possible NC-140 coordinated proposals to SCRI. The committee included M. Kushad (IL), P. Hirst (IN), W. Autio (MA), G. Fazio (NY) and possibly G. Lang (MI).

Technology Committee State reports are to be uploaded in the members-only section of the NC-140 website. Updated project proposal has been posted on NC-140 home page.

Tree spacing calculator needs fine-tuning (http://www.umass.edu/fruitadvisor/m/). Alphabetization of varieties would improve ease of use. A drop-down menu of site-specific climate would further aid in calculation of proper spacing.

Outreach/Extension Activities

Website The project website at http://www.nc140.org/ serves as an important information portal for information developed by this project. The website is hosted and maintained by W. Cowgill (NJ) and J. Clements (MA). Articles, photographs and research reports, along with annual meeting minutes and annual project reports are archived throughout the year.

Grower Meetings and Field Days Each year several members of the NC-140 project make presentations to fruit grower audiences on the results of this project. Similarly, in each cooperating state the coordinated field trials are used as venues to present information from this project to fruit growers at field days. A sample of the presentations given and field days held in 2008 are:

- The 2007 Wisconsin Summer Apple Field day was held at the Peninsular Ag. Research Station where these plantings are located and were among the reasons for hosting the field day at that location. 100 growers attended and had the opportunity to look at the plantings and ask questions.
- Representatives from the Massachusetts program presented fruit tree rootstock information at over 20 grower meetings and field days throughout 2007. The attendance at these events ranged from 10 to 350.
- Two presentations on the NC-140 rootstock research were made during field days at the Kaysville Research farm in Utah during 2008. The first included Agriculture Experiment Station employees from neighboring states. The second was attended by commercial growers from both Utah and Idaho.
- A field day was held in July, 2008 at Highmoor Farm in Monmouth, ME to highlight NC-140 research.
- The Iowa Fruit and Vegetable Growers Association Field Day was held on June 30, 2008 at the ISU Horticulture Research Station in Ames, IA. The NC-140 2003 apple rootstock trial was featured. 50 people attended.
- A presentation entitled "Apple rootstocks and training systems" was given at the Iowa Master Gardener Summer Session on July 12, 2008 at the ISU Horticulture Research Station in Ames, IA. Attendance was 60.
- North Jersey Fruit Meeting, March 2008; Broadway, NJ, 74 growers in attendance.
- North Jersey Twilight Fruit Meeting, April, 2008; Rutgers Snyder Farm, Pittstown, NJ, 44 growers in attendance.
- South Jersey Field Day and Tour, August 2008; RAREC, Upper-Deerfield, NJ. 85 attendees including growers, industry and extension personnel.
- North Jersey Twilight Horticultural Research Meeting, Rutgers Snyder Farm, September, 2008; sponsored by RCE and NJ NOFA. 66 growers participated.

PUBLICATIONS

- **Refereed journal articles**

- Autio, W., T. Robinson, W. Cowgill, C. Hampson, M. Kushad, G. Lang, J. Masabni, D. Miller, R. Parra Quezada, and C. Rom. 2009. Performance of 'Gala' apple trees on supporter 4 and different strains of B.9, M.9, and M.26 rootstocks as part of the 2002 NC-140 apple rootstock trial. Acta Hort. 11 pp. (in press).
- Autio, W., T. Robinson, J. Cline, R. Crassweller, C. Embree, E. Hoover, G. Lang, J. Masabni, M. Parker, G. Reighard and M. Warmund. 2009. Performance of several semidwarfing rootstocks with 'Fuji' and 'McIntosh' as scion cultivars in the 1999 NC-140 semidwarf apple rootstock trials. Acta Hort. 11 pp. (in press).
- Autio, W., T. Robinson, J. Cline, R. Crassweller, C. Embree, E. Hoover, G. Lang, J. Masabni, M. Parker, G. Reighard, and M. Warmund. 2009. Performance of several dwarfing

rootstocks with ‘Fuji’ and ‘McIntosh’ as scion cultivars in the 1999 NC-140 dwarf apple rootstock trials. Acta Hort. 11 pp. (in press).

- Autio, W., T.L. Robinson, B. Black, T. Bradshaw, J.A. Cline, R.M. Crassweller, C.G. Embree, E.E. Hoover, K. Kosola, J. Masabni, M.L. Parker, R.L. Perry, G.L. Reighard, J.R. Schupp, and M. Warmund. 2008. 1999 NC-140 ‘Fuji’ and ‘McIntosh’ dwarf apple rootstock trials: An update after eight growing seasons. Compact Fruit Tree 41(1): 23-25.
- Autio, W., T.L. Robinson, B. Black, T. Bradshaw, J.A. Cline, R.M. Crassweller, C.G. Embree, E.E. Hoover, K. Kosola, J. Masabni, M.L. Parker, R.L. Perry, G.L. Reighard, J.R. Schupp, and M. Warmund. 2008. 1999 NC-140 ‘Fuji’ and ‘McIntosh’ semidwarf apple rootstock trials: An update after eight growing seasons. Compact Fruit Tree 41(1): 26-28.
- Autio, W., T. Robinson, W. Cowgill, C. Hampson, M. Kushad, J. Masabni, R. Parra Quezada, R. Perry and C. Rom. 2008. Performance of ‘Gala’ apple trees on Supporter 4, P.14, and different strains of B.9, M.9 and M.26 rootstocks: a five-year report on the 2002 NC-140 apple rootstock trial. J. Amer. Pomol. Soc. 62(3):119-128.
- Autio, W., T. Robinson, W. Cowgill, C. Hampson, M. Kushad, J. Masabni, D. Miller, R. Quezada, R. Perry, and C. Rom. 2007. Performance of ‘Gala’ apple trees on strains of B.9, M.9, and M.26 and new Cornell-Geneva, Morioka, and Pillnitz rootstocks: Early results from the 2002 NC-140 Apple Rootstock Trial. Compact Fruit Tree 40. (In press).
- Hampson, C. R. and P. L. Sholberg. 2008. Estimating combining ability for fire blight resistance in apple progenies. Acta Hort. 793:337-343.
- Kushad, M. 2008. Performance of ‘Buckeye Gala” on nine rootstocks in the 2002 NC.140 trial. Trans. IL Hort. Soc. 69-71.
- Kushad, M. 2008. Performance of ‘Michel Gala’ on twelve rootstocks in a replant site. Trans. IL Hort. Soc. 72-73.
- Marini, R.P., R. Moran, C. Hampson, M. Kushad, R.L. Perry and T.L. Robinson. 2008. Effect of dwarf apple rootstocks on average ‘Gala’ fruit weight at six locations over three seasons. J. Amer. Pomol. Soc. 62(3):129-136.
- Masabni, J., R. Andersen, A. Azarenko, G. Brown, J. Freer, R. Hayden, P. Hirst, B. McCluskey, R. Perry, R. Robinson and D. Wolfe. 2007. Performance of plum rootstocks with 'Stanley', 'Valor' and 'Veeblue' as the scion in the 1990 NC-140 multi-site plum trial. J. Amer. Pomol. Soc. 61(4):196-207.
- Masabni, J., R. Andersen, A. Azarenko, G. Brown, J. Freer, G. Reighard, P. Hirst, D. Hayden, W. Lay, B. McCluskey, T. Robinson, G. Tehrani, D. Wolfe. 2007. Performance of plum rootstocks with ‘Stanley’, ‘Valor’, ‘Veeblue’, and ‘Santa Rosa’ scions in the 1991 NC-140 multi-state plum trial. J.Amer. Pom. Soc. (Needs revision).
- Reighard, G.L., D. R. Ouellette, and K. H. Brock. 2008. Performance of new *Prunus* rootstocks for peach in South Carolina. Acta Hort. 772:237-240.

- **Non-Refereed Journal Articles**
- Autio, W., J. Krupa, and J. Clements. 2007. Crop load and rootstock interact to affect 'Golden Delicious' tree growth, fruit size, and ripening: 2003 NC-140 apple rootstock physiological trial. Fruit Notes 72(1):14-17.
- Autio, W., J. Krupa, and J. Clements. 2007. Performance of McIntosh apple trees on one Pillnitz and three Geneva semidwarfing rootstocks: Nine-year summary of the 1999 NC-140 semidwarf apple rootstock trial. Fruit Notes 72(2):14-15.
- Autio, W., J. Krupa, and J. Clements. 2007. Performance of McIntosh apple trees on several Geneva and Pillnitz dwarfing rootstocks: Nine-year summary of the 1999 NC-140 dwarf apple rootstock trial. Fruit Notes 72(2):10-13.
- Autio, W., J. Krupa, and J. Clements. 2007. Comparison of strains of B.9, M.9, and M.26 to new Polish and Pillnitz dwarfing apple rootstocks: Six-year summary of the Massachusetts planting of the 2002 NC-140 apple rootstock trial. Fruit Notes 72(2):16-17.
- Autio, W., T.L. Robinson, B. Black, T. Bradshaw, J.A. Cline, R.M. Crassweller, C.G. Embree, E.E. Hoover, K. Kosola, J. Masabni, M.L. Parker, R.L. Perry, G.L. Reighard, J.R. Schupp, and M. Warmund. 2008. 1999 NC-140 'Fuji' and 'McIntosh' dwarf apple rootstock trials: An update after eight growing seasons. Compact Fruit Tree 41(1): 23-25.
- Autio, W., T.L. Robinson, B. Black, T. Bradshaw, J.A. Cline, R.M. Crassweller, C.G. Embree, E.E. Hoover, K. Kosola, J. Masabni, M.L. Parker, R.L. Perry, G.L. Reighard, J.R. Schupp, and Warmund, M. 2008. 1999 NC-140 'Fuji' and 'McIntosh' semidwarf apple rootstock trials: An update after eight growing seasons. Compact Fruit Tree 41(1): 26-28.
- Reighard, G.L. 2008. New and emerging rootstocks. Ernie Christ Memorial Lecture. Penn. Fruit News. Vol. 87(5):19-23.

- **Published Abstracts**
- Black, B.L., D. Drost, T. Lindstrom and G.L. Reighard. Sampling to compare relative root distribution in fruit trees. 9th Intl. Symp. on Integrating Canopy, Rootstock and Env. Physiol. in Orchard Syst. August 4-8, 2008. Geneva, NY, USA. (Abstr.)
- Clements, J.M., W.P. Cowgill, W. R. Autio, and D. Ward. 2008. Five-year performance of three dwarf apple rootstocks with 'Cameo'^{TM} apple. HortScience. 43(4): 1194. (Abstr.)
- Cowgill, W.P., Jr., N. Polanin, P. Nitzsche, R. Magron, J. Gyurian, E. Dager. 2008. Rutgers NJAES Snyder Research and Extension Farm – master gardener involvement in research, extension and community outreach. HortScience. 43(4): 1174. (Abstr.)

- **Books or Book Chapters**
- Reighard, G.L**.** and F. Loreti. 2008. Rootstock development. In: Layne, D.R. and D. Bassi (Eds.) *The Peach: Botany, Production and Uses*. CAB Intl, Wallingford, U.K., pp. 193-220.

- **Other Publications and Presentations**

- Cowgill, W.P., W. R. Autio, J.M. Clements. 2008. Using naphthalene acetic acid (NAA) to reduce shoot growth when a heading cut is used to lower tree height in super-spindle apple trees. Rutgers Annu. Conf.

- Domoto, P. 2008. 2003 NC-140 dwarf apple rootstock trial performance in 2007. Ann. Prog. Rept. – 2007 Hort. Res. Sta., ISRF07-36:28-29.

- Hu, Q., Z. Li, G. Reighard, and H. Luo. 2008. Genetic engineering of drought and salt tolerance in peach tree. 4th International Rosaceae Genomics Conference. Pucon, Chile. March 16-19, 2008.

- Lang, G., J. Freer, H. Larsen, R. Pokharel, T. Robinson, and T. Valentino. 2008. Differences in mineral nutrient contents of dormant cherry spurs as affected by rootstock, scion, and orchard site. Poster presented at the 9th Intl Symp. on Integrating Canopy, Rootstock and Env. Physiol. in Orchard Syst. August 4-8, 2008 in Geneva, NY.

- Liu, X., G.L. Reighard, G. A. Swire-Clark, W. C. Bridges, and W. V. Baird. 2008. Mapping the nuclear genome region associated with the Peach Tree Short Life Syndrome using microsatellite/SSR markers. 4th International Rosaceae Genomics Conference. Pucon, Chile. March 16-19, 2008.

- Masabni, J.G., and D.E. Wolfe. 2007. Rootstock and interstem effects on pome fruit trees. 2007 Fruit and Veg. Crops Res. Rpt. Univ. of Kentucky College of Agr., Agr. Exp. St. Publ. PR-555:50-52.

- Masabni, J.G., and D.E. Wolfe. 2008. Rootstock and interstem effects on pome fruit trees. 2008 Fruit and Veg. Crops Res. Rpt. Univ. of Kentucky College of Agr., Agr. Exp. St. Publ. (In press).

- Moran, R.E., D.Z. Zhang, and Y. Sun. 2008. Cold temperature tolerance of apple roots. The 9th International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems, Geneva, NY.

- Reighard, G.L., T. Beckman, R. Belding, B. Black, J. Cline, W. Cowgill, R. Godin, R. S. Johnson, M. Kaps, H. Larsen, T. Lindstrom, D. Ouellette, R. Pokharel, L. Stein, K. Taylor, C. Walsh, and M. Whiting. Performance of *Prunus* rootstocks in the 2001 NC-140 peach trial. ISHS Symposium, Geneva, NY. August 4-8, 2008.

- Reighard, G.L., D. R. Ouellette, and K. H. Brock. 2008. Performance of new peach rootstocks in South Carolina. SR-ASHS. Dallas, TX. February 4, 2008.

- Reighard, G.L. 2008. New and emerging rootstocks. Ernie Christ Memorial Lecture. Mid-Atlantic Fruit and Vegetable Convention. Hershey, PA. January 29-31, 2008.

- Ward, D., G. Loki, W.P. Cowgill Jr., J.L. Frecon, G.C. Hamilton, J.R. Heckman, L.S. Katz, N. Lalancette, B.A. Majek, D. Polk, P.W. Shearer, W.H. Tietjen. 2008. "New Jersey commercial tree fruit production guide." Rutgers Coop. Ext. Bul.E002. 232pp.

Appendix: Individual State Accomplishments and Impacts in 2008

Arkansas:

British Colombia: A windstorm snapped off two trees at the graft union. Both trees were on B9 TRECO, including one inside the plot, and no other trees were affected. Several other plots at the research station also had graft union breakage with trees on B9 during the same storm. Suckering was higher this year than previously; certain trees on M.9 subclones have had a lot of suckers cumulatively over 7 years, and on average, trees on B9 Europe had more suckering than trees on B9 TRECO. After 6 growing seasons, trees on PI5683, JM2 and PI514 are much larger than the others and do not appear to be in the semi-dwarf or smaller vigour classes (Table 2). All have rather low cumulative yield efficiency, low suckering and good fruit size. Rootstock producing trees approximately the size of those on M.26 included GC6210, JTEH, CG5935, PI5111, JM8, JM7. JM8 cannot be recommended due to poor survival. Cumulative number of suckers was high on certain trees on PI5111, CG6210, JTEH and CG5935, and overall they all had more suckers than trees on M.26. Trees on CG5935 had excellent cumulative yield efficiency, and trees on PI5111 were very inefficient. Trees NSD from M.9T337 in size included those on CG3041, G.16, B62396 and M9 Pajam2. Pajam 2 had an undesirable degree of suckering but was otherwise NSD from M.9T337 in performance. G.16 appears undesirable due to rather poor survival, greater suckering and lower yield efficiency than M.9. This year it also had small fruit size despite very low crop load. CG3041 and B62396 had good survival, high efficiency and possibly fewer root suckers than trees on M.9T337. The trees on B9 in this planting are unusually small (smaller than M.9) and I believe they are runting out. This is a concern. I have also had scattered reports from commercial growers experiencing the same problem with B.9, which is widely used in this region. Rootstocks JM1, B9 and JTEG produced trees significantly smaller than those on M.9, and too small to be of interest commercially in this vicinity. Trees on JM1 had poor survival and small fruit. JTEG trees are similar in size to those on M.27 in previous trials, but unlike M.27, it has good fruit size. Trees on JTEG had virtually no suckering. In general, tree health/survival on JM1, JM7, JM8 and G.16 has been lower than desirable for commercial usage Trees on JM2, P14, Supporter 4, PI5683, PI514 and JM2 appear to be larger than the size desired for local high density plantings. Trees on JM1 and JTEG were too small for our uses. Several rootstocks with vigor in the M.26 and M.9 size classes and equal or better productivity have been tentatively identified. Some of them have detractive features (more tree deaths, more root suckers) but others are very interesting and some are reportedly resistant to fire blight. B.9 trees in one of the two trials seem to be “runting out”. A poster on the response of four Vineland rootstocks (V.1, V.2, V.3 and V.4) to flooding and crown rot was presented at a scientific meeting. All the Vineland stocks appeared to have resistance as good as, or better than, M.9 EMLA to either flooding and Phytophthora infestation, or a combination of the two, and all greatly exceeded MM.106 in resistance.

California: In the 2003 Golden Delicious Apple Rootstock Planting, tree death was not a major factor in this block in 2008 as it had been in previous years. Only 5 trees died and 3 of those were due more to neglect than to disease. One tree each on M.26, JM.7 and CG.3041 broke off below the graft union, which probably would not have happened if they had been more securely staked. One tree on PiAu 56-83 died, most likely from fireblight and one on J-TE-G also collapsed. Both B.9 and J-TE-G are such weak trees under the stressful conditions of California, that they have been slowly dying off since planting and will likely continue until they are all dead. During the 2008 season, the trees carried a much greater crop load than they did the year before but fruit weight remained about the same (Table 1). The trees with the greatest yield were on rootstocks CG.4210, PiAu 51-4, PiAu 56-83 and G.16. The PiAu trees are very large, but the other two are more semi-dwarfing. In general, the bigger trees had larger fruit. The most notable exception to this was JM.1 which had very large fruit but is only a moderately large tree. Clearly, some trees in this trial are much too vigorous for the spacing. In terms of tree size, survival, productivity and fruit size, the most promising semi-dwarfing rootstocks after 6 seasons of evaluation are CG.4210, CG.5179, G.16, J-TE-H and JM.1.

In related rootstock work, the peach rootstock breeding program includes a large number of selections from a wide array of crosses. In 2001, several of these with O'Henry peach grafted on top looked to be extremely promising. The trees ranged in size from very dwarfing to semi dwarfing and all had excellent fruit size. More than 20 of these have been identified and were planted in a large replicated trial in 2003, 2004 and 2005. Several went out in grower trials in 2007 and 2008.

Colorado: After the removal of the 2001 and 2002 peach rootstock trials, the only NC-140 rootstock planting remaining in Colorado is the 1998 sweet cherry rootstock trial for which data collection was completed in 2006. However, the sweet cherry rootstock block is being used for a preliminary study on control options for Cytospora canker of stone fruit, association of plant parasitic nematodes and cherry rasp leaf virus infection evaluation studies. Nematode sampling is completed; no significant differences were observed for rootstocks and associated plant parasitic nematode populations, especially, dagger nematode. Some trees in this block have already shown symptoms of cherry rasp leaf virus. To ensure the uniformity of inoculum, viruliferous dagger nematodes will be introduced throughout the block and rasp leaf virus development will be monitored to study any difference in virus infection in these rootstocks.

A new apple rootstock trial to evaluate rootstocks for alkaline conditions was initiated in collaboration with Dr. Gennaro Fazio, USDA, Geneva. The trial, planted in 2008, has 23 rootstocks and excellent tree growth was observed in the first growing season.

Georgia:

Illinois: In the 2006 'Gala' replant trial, no differences were observed between the non-fumigated and fumigated treatment. However, more trees died of the non-fumigated than the

fumigated treatment. There were significant differences in TCSA among the rootstocks. M.7 is the largest, followed by G.11, and G.5935. The smallest rootstock is G.4210. Rootstocks also differed in tree height and spread with M.7 being the tallest with the widest spread, while B.9 and eight others were the shortest. G.4210 has the narrowest spread with 1.38 meter. Rootstocks also differed in yield, with G.16 producing the largest number of fruits and the greatest fruit mass, while M.7 producing the least number of fruits and the lowest fruit mass.

Iowa: In the 2003 apple rootstock planting, based on trunk cross sectional area, trees on PiAu 51-4, PiAu 56-83, PiAu 36-2, JM.5 and JM.2 continue to be the largest, while trees on J-TE-G, and B.9 remain the smallest (Table 1). Even with light crop loads in 2007, trees on JM.5, PiAu 36-2, PiAu 51-4, PiAu 56-83, JM.4, and JM.10 failed to come back with a normal bloom and remain the least productive. On a cumulative basis, trees on J-TE-G have been the most productive, followed by B.9, JM.7, CG.3041, G.16 and CG.5935. Even with a low crop load, trees on JM.10 produced the smallest fruit. Trees in the Iowa planting received excessive rainfall in May (23.3 cm), June (26.5 cm) and July (17.1 cm). In August, trees on B.9 (which does not tolerate wet soils), G.16, and PiAu 51-11 exhibited signs of reduced vigor characterized by pale foliage and somewhat smaller leaves. The 2007-08 winter was unusual with prolonged periods of below freezing temperatures with few periods conducive to de-acclimation or prolonged periods of subfreezing temperatures conducive to attaining maximum cold tolerance being recorded, and it was early April before 1,000 hours of chilling was accumulated. The coldest temperature (-27.2 C, -17 F) was recorded on 24 January. At the end of the growing season dead rootstock bark was observed on 2 trees on J-TE-G (100% and 60% girdled) and 2 trees on PiAu 51-11 (60% and 20% girdled). The tree with 100% dead rootstock bark produced a crop with no reduction in fruit size. It is assumed that the injury was from low temperature stress and that it occurred during the 24 January freeze. Rootstocks in the Iowa planting have been exposed to extremes of low winter temperatures and excess soil moisture. Testing rootstocks under such conditions has identified J-TE-G and PiAu 51-11 as being sensitive to winter stress and G.16 being as sensitive as B.9 to wet soil conditions.

The 2003 apple physiology study was carried out in 2006 and was to be repeated in 2008. However, fruit set was not great enough to apply the high fruit load treatments. As a result, the trees were hand thinned to a reduced load with plans to repeat the study in 2009.

Indiana: A planting of Buckeye Gala growing on 11 rootstocks was established in 2002 at the Purdue Meigs horticultural research farm near West Lafayette, IN. Trees have been manage according to NC□140 protocols, which in general mimic best commercial practice. Tree survival has generally been very good, except for trees on B.9Europe trees. Trees on both B.9 rootstocks is quite variable, I think mainly due to burr knots and root suckers. Other rootstocks have performed quite well and generally yield efficiency has been good. A notable exception is PiAU 51□11 which appears to be less yield-efficient. Bear in mind that trees carried a very light crop

in 2007 due to a late spring frost. The light crop the previous year may account for the excellent fruit size achieved by trees on all rootstocks.

A planting of Gibson Golden Delicious growing on G.16, M.26 and M.9 rootstocks was established in 2003 at the Purdue Meigs horticultural research farm near West Lafayette, IN. Trees have been managed according to NC□140 protocols, which in general mimic best commercial practice. The one exception to standard management techniques was the imposition of crop loads. A range of crop loads was imposed on the trees by hand thinning soon after bloom. Although there was some variation in crop load, we were not as successful as we would have liked in imposing differing crop loads. However, fruit number per tree ranged from 44 to 387. There appeared to be little effect of rootstock on the relationship between fruit fresh weight and the number of fruit per tree (Figure 2). Once tree size was taken in to account, there were stronger relationships between fruit size and crop load (fruit number per cm2 TCSA) but again these relationships did not appear to be influenced by rootstock.

Kentucky: All of the NC-140 trials in Kentucky are located at the Research and Education Center in Princeton, KY. These include the 1999 dwarf and semi-dwarf apple rootstock trials, the 2002 apple rootstock trial, and the 2003 apple rootstock and physiology trials. As reported in 2007, all of our NC-140 apple plantings at UKREC sustained damage that severely reduced yield in that year due to a series of devastating freezes from April 5 through April 10, 2007 that affected all fruit crops in Kentucky. This year, Hurricane Ike blew through western and northern Kentucky on September 14, 2008. At UKREC, some fruit was blown off of trees and some trees were broken at either the graft union or at their roots just below the soil line. Nevertheless, the heavy bloom this past spring and a generally excellent growing season resulted in excellent yields at harvest. Among the dwarf rootstocks planted in 1999, CG.202 and CG.5179 yielded the most fruit in 2008, while G.30N yielded the most fruit among the semi-dwarf trees. G.30N also had the highest cumulative yield. Cumulative yield was greatest for CG.41 and CG.4013 among the dwarf rootstocks. In the 2002 rootstock trial, M.9 Burgmer756 yielded the most fruit in 2008 and had the highest cumulative yield. Trunk cross-sectional area was highest for P.14 followed by M.9 Burgmer756. Cumulative yield efficiency was the highest for the two B.9 rootstocks. Trees on PiAu51-4 and PiAu56-83 yielded the most fruit in 2008. They also had the highest cumulative yields, and were the biggest trees in this trial. Trees in the physiology trial were thinned differentially to crop loads of 2, 4, 6, 8, and 10 fruit per square centimeter of trunk cross sectional area in 2008. Neither crop load treatment nor rootstock significantly affected yield in 2008 or cumulative yield. Fruit size was greatest for trees thinned to 4 fruit per cm^2 of trunk cross-sectional area. Mortality was highest for scions on M.26.

Maine: The 2003 NC-140 Golden Delicious rootstock and physiology plantings were maintained according to NC-140 protocol. Rootstock Study. In 2008, trees with small trunk circumference than M.26 included JTEG, B.9, and M.9 T337. Trees on JM8, CG6210, PI514, JM2 and PI5683 had larger trunk circumference than M.26. Trees on other rootstocks were

similar in size to M.26. Compared to M.9 T337, JTEG was the only rootstock with significantly smaller trunk size. B.9, Pajam2, Pajam2, PI5111 and CG.3041 had similar trunk size as M.9 T337 and the other rootstocks had larger trunk size. Yield efficiency on JTEG and JM2 was greater than for M.26, but other rootstocks had similar yield efficiency as M.26. G.16, JTEH, M.26, B.62396, PI514 and PI5683 had lower yield efficiency than M.9 T337and the other rootstocks had similar yield efficiency.

In the 2003 apple physiology study, trees were in the off year, so fruit were removed by hand during fruit set to promote abundant return bloom. Return bloom decreased with increase in last year's crop density.

Cold Hardiness Testing of New Apple Rootstocks (local project): G.5935 had greater root tissue cold hardiness than M.26 EMLA, based on shoot growth following exposure to freezing temperatures to a low of -16 °C. Rootstocks were stored in a cold room at temperature of 1°C from November to February. Cold hardness was evaluated after subjecting ungrafted whole trees to a drop in temperature from 0 to -16 °C. Relative electrical conductivity of root tissue increased linearly with exposure to decreasing temperature and increased at a greater rate for M.26 EMLA than for G.5935. Shoot growth of M.26 EMLA was reduced by exposure to -12 C and colder, whereas, G.5935 was not reduced until exposure to -14 and colder.

Changes in rootstock selection can increase yield and tree survival leading to greater profitability. Knowledge of correct tree spacing can prevent economic losses. Impacts will be measured as changes in the industry and will be documented through grower surveys.

Maryland:

Massachusetts: Dwarf Apple Rootstock (1999, McIntosh, 2008 results). Largest trees were on CG.4013. Smallest were on M.9 NAKBT337, Supporter 1, Supporter 2, and Supporter 3. Cumulatively (2001-08), trees on CG.4013 yielded the most. Trees on CG.5179 and G.202 were the next greatest yielding, followed by those on G.41, Supporter 3, M.26 EMLA, G.16T, and Supporter 2, and lowest yields were from trees on G.16N, M.9 NAKBT337, and Supporter 1. Trees on Supporter 1 and Supporter 2 were significantly more yield efficient than those on G.16N.

Semidwarf Apple Rootstock (1999, McIntosh, 2008 results). Largest trees were on M.7 EMLA, Supporter 4, and G.30N, all significantly larger than those on M.26 EMLA, CG.4814, and CG.7707. Cumulatively (2001-08), trees on G.30N yielded more than those on CG.4814, CG.7707, or M.26 EMLA, and CG.4814 resulted in the most yield-efficient trees, followed by those on CG.7707, M.26 EMLA, and G.30N. Trees on M.7 EMLA and Supporter 4 were the least efficient.

Apple Rootstock (2002, Gala, 2008 results). Largest trees were on PiAu51-4, followed in decreasing size by those on P.14, PiAu51-11, M.26 NAKB, Supporter 4, M.26 EMLA, M.9 Burgmer 756, M.9 Nic 29, M.9 NAKBT337, B.9 (Treco), and B.9 (Europe). Greatest cumulative yields (2004-08) were harvested from trees on M.26 NAKB, and lowest were harvested from

trees on B.9 (Europe). The two B.9 strains resulted in the greatest yield efficiency, while PiAu51-4 resulted in the lowest.

Apple Rootstock Physiology (2003, Golden Delicious, 2008 results). Size of trees on M.26 EMLA was significantly greater than that of trees on G.16, which was significantly greater than the TCA of trees on M.9 NAKBT337. Cumulative yield efficiency was greater for trees on M.9 NAKBT337 than those on M.26 EMLA. M.9 NAKBT337 resulted in a greater spur density and a comparable percent of spurs blooming to the other two rootstocks. The result was double the blossom density of trees on M.9 NAKBT337 compared to those on G.16 or M.26 EMLA. Crop load in 2007 significantly and negatively affected blossom density in 2008, primarily by negatively affecting the percent of spurs blooming. Crop load in 2008 was positively related to blossom density and percent of spurs blooming in 2008. There was a negative correlation between crop load in 2007 and crop load in 2008. Crop load in 2007 was negatively correlated with fruit weight in 2008, even though it was negatively correlated with crop load in 2008. The result was a positive correlation between crop load in 2008 and fruit weight in 2008.Trees were stressed by the high crop loads imposed in 2007 to the point where that stress was carried into the next season.

Apple Replant Disease (ARD) issues are becoming more prevalent in New Jersey. The NC-140 Regional Research Project on rootstocks is designed to address a number of high-priority areas in tree fruit production, one of which is ARD. Poor growth and survival are typical of apples replanted into apple ground due to ARD. Soil preparation began in spring 2005 with removal of existing apple trees. The soil wasprepped with numerous tillage operations to remove all roots and debris in an 8-foot band. This band was keptfallow the remainder of 2005. Nematode samples were collected pre-fumigation in fall of 2005. Turf type tallfescue was established between the planting strips in Sept 2005. Soil fumigation with Telone was completed thefall of 2005 as one treatment. Trees were established according to protocol in April 2006. Ditera nematicide (Valent Bioscience) was applied post plant as a second treatment in five monthly applications. Nematode samples by treatment and replication were taken and submitted to the Rutgers Diagnostic lab for analysis in September 2007. Data will be presented in 2009.

Shoot Length Measurements 2006 Apple Replant Disease Trial Shoot length was measured on all shoots in 2007; this permitted analysis of the percentage of shoots that were shorter than 5 cm. The cutoff of 5 cm was used to separate extension shoots from short shoots (spurs). Shoots were categorized as short or not and the binomial response was analyzed using a generalized mixed linear model (SAS PROC GLIMMIX) to test for main effects of treatment (Control, Telone, or Diterra) and rootstock as well as their interaction. Similar to shoot length, there was a significant main effect of rootstock on the percentage of short shoots ($P<0.001$, Table 5) but the main effect of treatment and treatment by rootstock interaction were not significant ($P=0.6867$ and $P=0.6143$ respectively). Rootstocks with longer average shoot lengths tend to have a lower percentage of short shoots. This suggests that the rootstock is inducing a shift in the population of shoots and at this early age creating a cohort of short shoots that will affect the spur systems that develop.

Michigan:

Minnesota: In the NC140 1999 planting, tree size ranking has not changed significantly in the either planting. In the dwarf planting, Supporter 1 is the smallest tree and CG.4013 the largest. Yield for the Cornell-Geneva rootstocks was almost always significantly higher in the dwarf planting than the other rootstocks under evaluation. In the semi-dwarf planting, CG.4210 has produced well, and might be an interesting rootstock to evaluate further. A 2003 rootstock trial of Minnesota breeding selection 'Snowsweet'™ continues, with no significant changes in tree size ranking. Trees on B.9 continue to produce the lowest yield and smallest fruit. CG.5030 produced the highest yield, while V.1 produced the largest fruit. A rootstock trial of Minnesota breeding selection 'Sweetango'™ (formerly MN1914) was also planted in 2003. This planting was affected by a damaging wind event in 2007, greatly reducing the number of trees in the planting. Trees on B.9 are the smallest trees and continue to produce the lowest yield. Trees on M.7 are the largest trees and produce the largest fruit. A 2001 Honeycrisp rootstock trial showed no significant changes in tree size ranking. These trees remain small in comparison to other plantings.

New Jersey: All protocols were followed in 2008. All data was collected in 2008. Maintenance pesticide applications were timed utilizing NJ's pest management protocols following weekly scouting. Weather was excellent in northern NJ for pollination and fruit set and growth throughout the summer. Bright sunny days in the fall made for excellent harvest weather. Adequate rainfall supplemented with drip irrigation on all plots throughout the summer provided for good fruit growth and development. A severe weather event occurred on August 17, 2007. Hail and high winds in excess of 75 MPH hit the Rutgers Snyder Research and Extension Farm. Trees and flower buds for 2008 were appeared to be severely impacted. However return bloom was very strong especially on peaches. The impact side of the trees (west) appeared to have slightly less fruit than the eastern side across all blocks.

In 2002, a trial was established at the Rutgers Snyder Research and Extension Farm, Pittstown NJ and at UMASS Cold Spring Orchard Research and Education Center, Belchertown, MA. The cultivar was Cameo on B.9, G.16 and M.9 NAKBT377. The experiment was a randomized complete block design with ten replications at each site. Only NJ data is presented. Cameo is an important new cultivar for our direct sales oriented growers. Information on its performance on G.16, M.9 NAKBT377 and B.9 will assist us in making recommendations to growers.

As part of the 2002 NC140 Apple Rootstock Trial, a planting of 11 rootstocks were established at the Rutgers Snyder Research and Extension Farm, Pittstown NJ with the Buckeye Gala as the scion. The trial planting included seven replications in a randomized complete block design. Tree growth was excellent in 2007. In 2007 there was no significant difference in average fruit size (weight). Rootstocks affected TCSA, yield, yield efficiency, cumulative yield,

cumulative yield efficiency, root suckers and burr knots. Note that this trial was picked approximately seven days before maturity due to the hailstorm on August 17, 2007.

As part of the 2003 NC-140 Apple Rootstock Trial, a planting of Gibson Golden Delicious on 3 rootstocks was established at the Rutgers Snyder Research and Extension Farm, Pittstown NJ. The planting included ten trees of each rootstock in a completely random design. Two guard rows were established with Gibson Golden Delicious. This year was the off year for this trial. Hail destroyed 100% of the fruit in this trail on 17 August 2007 so no yield or fruit size data was taken. Rootstock significantly affected TCSA as well as number of root suckers per tree.

New York:

North Carolina: The NC-140 trials continue to be an educational tool for growers in the Southeast to help in their decision making of rootstocks to consider in their high to medium density orchards. Data from the NC-140 plantings are presented at grower meetings and orchard tours in the plantings are also utilized to educate our clientele about apple rootstocks. Much of the rootstock information is generated in more northern climates and this trial allows southeastern growers an opportunity to see and receive rootstock performance information for their growing conditions.

Although early in the life of the replant studies, it appears that soil fumigation may be beneficial for trees planted on some rootstocks. The goal of this study is to identify, if any, rootstocks that may be used in replant sites in southeastern apple orchards where survival and productivity can be maximized without the use of soil fumigants.

Ohio:

Oregon:

Pennsylvania:

South Carolina: Data from the 1999 'Nagafu 6' Fuji apple rootstock trial at the Musser Fruit Research Center near Clemson, South Carolina were recorded in 2008. One additional tree on M.9T337 died in 2008, most likely due to *Phytophthora spp*.

In the dwarf rootstock planting, trees on Geneva 16N rootstocks continued to be the most vigorous, and trees on Supporter #3 rootstocks were the least vigorous (Table 1). Fruit size was largest with Geneva 16N and CG.179 rootstocks, and smallest with Supporter #3 rootstocks. Geneva 16N rootstocks produced the highest yield in 2008 and also the highest cumulative yield. Fruit yield continued to be lowest with Supporter #1 and Supporter #3 rootstocks. Trees on CG.179 rootstocks had the highest yield efficiency in 2008, and trees on Supporter #2 had the highest cumulative yield efficiency.

In the semi-dwarf planting, trees on M.26 rootstocks were the most vigorous (Table 2). There were no significant differences in fruit size, fruit yield in 2008 or cumulative fruit yield. Cumulative yield efficiency continues to be highest with CG.814 rootstocks and lowest with M.26 rootstocks.

Tennessee:

Utah: Utah's 2008 growing season was marked by an unusually wet, cold spring. This ended on June 1, on which day we had daytime temps in the 30s and 40s with some snow pellets. Conditions then transitioned quickly into summer-like weather. Delays of 2-3 weeks in harvest time were observed in both Redhaven and Gala. Goldens were about a week later than normal. As a consequence of the extreme fireblight season in 2007, we were very proactive with fireblight protection in 2008. Very few fireblight strikes were observed, although we did have a few trees show systemic infection from 2007 infections that died during the 2008 summer.

With the continued loss of Utah's premium fruit growing sites to urbanization, more commercial fruit production is shifting to marginal sites characterized by increased risk of frost damage, higher pH soils (>8.0) and more saline soils and irrigation water. Identifying rootstocks that are adapted to these marginal soils and that provide the degree of cold hardiness required in Utah's high-elevation continental climate will be essential to the long-term survival of a local fruit industry. The results from the NC-140 work will be disseminated to commercial fruit producers in Utah to assist them in selecting rootstocks suited to their specific conditions.

Vermont:

Washington:

Wisconsin: Weather events were a factor in the poor productivity of some plantings. Drought conditions in the late summer and into the fall of 2007 stressed trees going into the winter. This was followed by a mid-winter thaw and quick drop in temperature in a less than 24 hour period (4.4 to -24.4°C late January). These events resulted in a complete loss of sweet cherry flowers in the bud and near complete loss with tart cherry. Some of the less winter hardy apple varieties may also have been affected in a similar way. In addition a frost in late May (-2.5°C), during early bloom, may have contributed to the less than ideal fruit set seen in varieties like Golden Delicious.

The current and past NC140 rootstock plantings have been valuable in helping to improve recommendations for commercial tree fruit producers here in Wisconsin. The identification of productive and winter hardy rootstocks, like Bud.9, has made it possible for growers to establish high density apple plantings with minimal concern and increased confidence regarding winter injury and tree survival. Newer rootstocks, including many in the CG series, are showing promise for future plantings.