ANNUAL REPORT TO NC-140

Massachusetts Agricultural Experiment Station

November, 2008 -- Cuauhtémoc, CH Mexico

Wesley Autio (leader), Jon Clements, James Krupa, & Daniel Cooley

PROGRESS & PRINCIPAL ACCOMPLISHMENTS

2003 NC-140 Apple Physiology

As part of the 2003 NC-140 Apple Rootstock Physiology Trial, a planting of Gibson Golden Delicious on three rootstocks was established at the University of Massachusetts Cold Spring Orchard Research & Education Center. Trees in this trial grew very poorly during their first two seasons. They grew well in 2005, 2006, and 2007, but fruit set was very low in 2006. In 2007, trees were allowed to crop and crop load was adjusted per recommendations for the experiment. In 2008, return bloom was assessed, and crop load of all trees was reduced to no more than about 3 fruit per cm^2 trunk cross-sectional area (TCA). The planting included ten trees of each rootstock in a completely random design. Means from 2008 (6^{th} growing season) are included in Tables 1 and 2 and Figures 1 and 2.

Table 1. Trunk cross-sectional area, suckering, yield, yield efficiency, and average crop load in 2008 of Gibson Golden Delicious trees on three rootstocks in the Massachusetts planting of the 2003 NC-140 Apple Rootstock Physiology Trial. All values are least-squares means, adjusted for missing subclasses.[z]

Rootstock	Trunk cross-sectional area (cm^2)	Root suckers (no./tree, 2003-08)	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Average fruit weight (g, 2006-08)
			2008	Cumulative (2006-08)	2008	Cumulative (2006-08)	
G.16	23.5 b	0.1 b	6.8 a	32 a	0.30 a	1.37 ab	177 a
M.26 EMLA	30.8 a	0.2 b	6.9 a	36 a	0.23 a	1.15 b	175 a
M.9 NAKBT337	18.7 c	1.7 a	6.6 a	28 a	0.37 a	1.56 a	189 a

[z] Means were separated within columns by Tukey's HSD ($P = 0.05$).

Table 2. Flowering, crop load, and fruit weight in 2008 of Gibson Golden Delicious trees on three rootstocks in the Massachusetts planting of the 2003 NC-140 Apple Rootstock Physiology Trial. All values are least-squares means, adjusted for missing subclasses.[z]

Rootstock	Blossom density (no. clusters /cm^2)	Spur density (no./cm^2)	Blooming spurs (%)	Crop load (no./cm^2)	Fruit weight (g)
G.16	4.4 b	14.6 b	31 a	1.6 a	166 ab
M.26 EMLA	4.2 b	13.7 b	31 a	1.4 a	154 b
M.9 NAKBT337	9.1 a	20.5 a	43 a	1.9 a	185 a
Correlation with:					
Crop load 2007	-0.54**	+0.20^{ns}	-0.70***	-0.68***	-0.64***
Crop load 2008	+0.93***	+0.17^{ns}	+0.85***	---	+0.70 ***

[z] Rootstock means were separated within columns by Tukey's HSD ($P = 0.05$).

At the end of the 2008 growing season, TCA 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 (Table 1). M.9 NAKBT337 resulted in significantly more root suckers (2003-08) than did G.16 or M.26 EMLA (Table 1). Yield per tree (2008 or cumulatively) was not affected by rootstock, nor was 2008 yield efficiency (Table 1). Cumulative yield efficiency was greater for trees on M.9 NAKBT337 than those on M.26 EMLA. Trees on G.16 were intermediate. Average fruit size (2006-08) was not different by root-

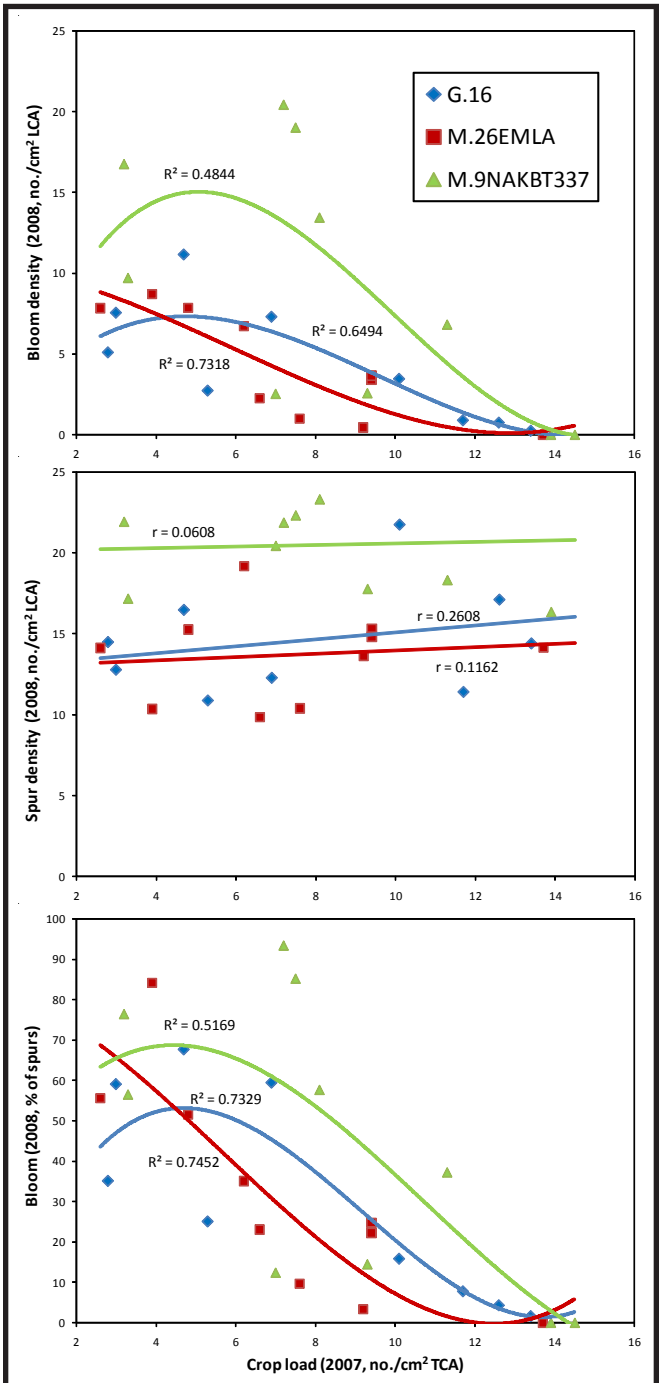

Figure 1. Effects of crop load in 2007 on flowering in 2008 of Gibson Golden Delicious trees on G.16, M.26 EMLA, and M.9 NAKBT337 rootstocks in the Massachusetts planting of the 2003 NC-140 Apple Rootstock Physiology Trial.

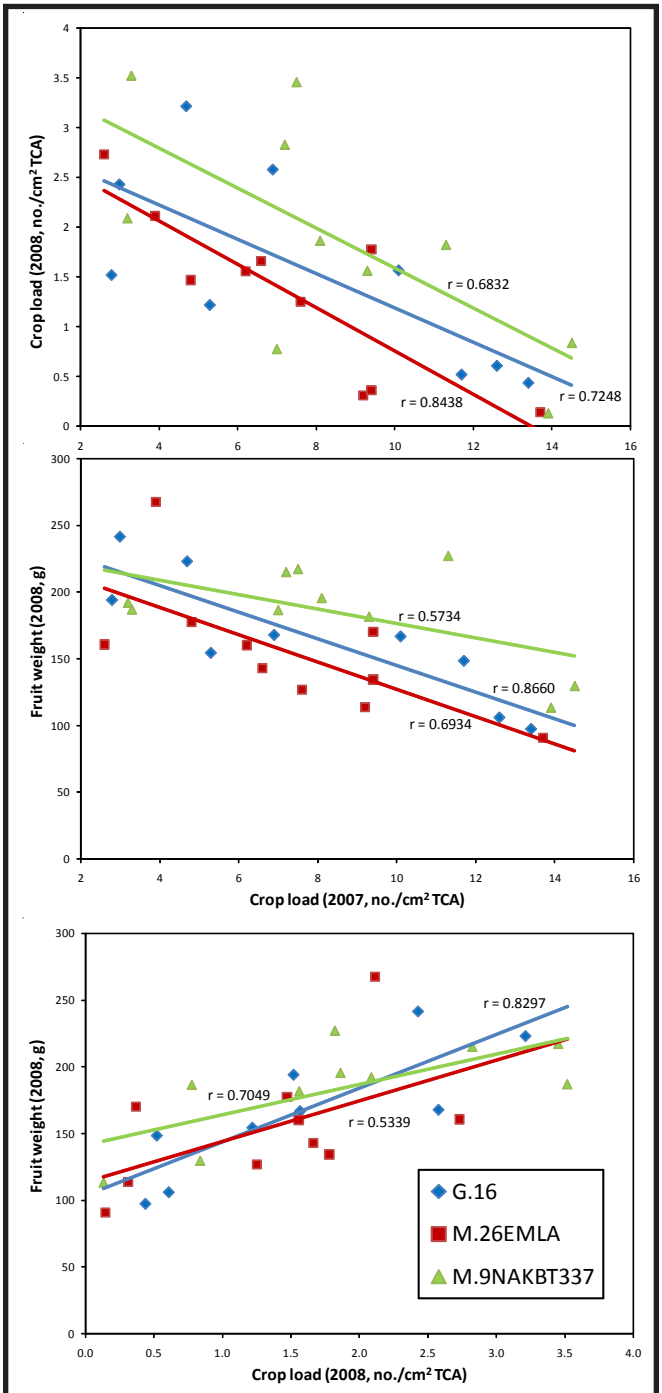

Figure 2. Effects of crop load in 2007 on crop load and fruit weight in 2008 and effects of crop load in 2008 on fruit weight in 2008 of Gibson Golden Delicious trees on G.16, M.26 EMLA, and M.9 NAKBT337 rootstocks in the Massachusetts planting of the 2003 NC-140 Apple Rootstock Physiology Trial.

stock (Table 1).

The purpose of this trial was to determine if crop load and rootstock interacted to affect tree physiology. The effects measured in the year of crop-load adjustment were reported last year. Here we report those effects seen in the year after crop-load adjustment. None of these relationships were affected by an interaction of rootstock and adjusted crop load.

Looking first at the effects on bloom, rootstock affected return bloom (Table 2, Figure 1). Specifically, 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 (Figure 1), primarily by negatively affecting the percent of spurs blooming (Table 2). As one would expect, crop load in 2008 was positively related to blossom density and percent of spurs blooming in 2008 (Table 2), even though crop loads were artificially reduced on some trees. Also as expected, there was a negative correlation between crop load in 2007 and crop load in 2008 (Table 2, Figure 2). The more interesting response was that crop load in 2007 was negatively correlated with fruit weight in 2008, even though it also was negatively correlated with crop load in 2008 (Table 2, Figure 2). The result was a positive correlation between crop load in 2008 and fruit weight in 2008 (Table 2, Figure 2). Clearly, these data show that trees were stressed by the high crop loads imposed in 2007 to the point where trees were significantly affected in the next year. This stress showed in the field as small leaves on trees that had fruited heavily the previous year.

Table 3. Trunk cross-sectional area, tree height, canopy spread, and root suckering in 2008 of McIntosh trees on several rootstocks in the Massachusetts planting of the 1999 NC-140 Dwarf Apple Rootstock Trial. All values are least-squares means, adjusted for missing subclasses.[z]

Rootstock	Trunk cross-sectional area (cm^2)	Tree height (m)	Average canopy spread (m)	Root suckers (no./tree, 1999-2008)
G.41	64 bc	3.4 bc	3.6 abcd	4.6 c
CG.4013	110 a	4.0 a	4.2 a	22.8 ab
CG.5179	72 b	3.8 ab	3.9 ab	25.8 a
G.202	76 b	3.8 ab	3.8 abc	4.0 c
G.16N	52 bcd	3.0 cd	3.4 bcd	0.0 c
G.16T	51 bcd	3.2 bc	3.4 bcd	2.8 c
M.26 EMLA	57 bcd	3.4 bc	3.7 abc	0.0 c
M.9 NAKBT337	39 cd	2.5 d	3.2 bcd	11.3 bc
Supporter 1	37 d	3.0 cd	2.9 d	1.7 c
Supporter 2	43 cd	3.0 cd	3.2 cd	1.8 c
Supporter 3	47 cd	3.4 bc	2.9 d	7.5 c

[z] Means were separated within columns by Tukey's HSD (P = 0.05).

Table 4. Yield, yield efficiency, and fruit weight in 2008 of McIntosh trees on several rootstocks in the Massachusetts planting of the 1999 NC-140 Dwarf Apple Rootstock Trial. All values are least-squares means, adjusted for missing subclasses.[z]

	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Fruit weight (g)	
Rootstock	2008	Cumulative (2001-08)	2008	Cumulative (2001-08)	2008	Average (2001-08)
G.41	57 abc	239 bcd	0.9 a	3.7 ab	183 a	171 ab
CG.4013	77 a	364 a	0.7 a	3.4 ab	187 a	168 ab
CG.5179	70 ab	301 ab	1.0 a	4.3 ab	171 a	162 ab
G.202	62 abc	296 abc	0.8 a	3.9 ab	193 a	169 ab
G.16N	46 abc	166 d	0.9 a	3.2 b	187 a	167 ab
G.16T	41 abc	202 bcd	0.8 a	4.0 ab	197 a	163 ab
M.26 EMLA	53 abc	210 bcd	0.9 a	3.7 ab	175 a	166 ab
M.9 NAKBT337	39 bc	146 d	1.0 a	3.7 ab	183 a	174 a
Supporter 1	34 c	173 d	1.0 a	4.7 a	183 a	165 ab
Supporter 2	43 abc	199 cd	1.0 a	4.7 a	169 a	153 b
Supporter 3	38 bc	217 bcd	0.8 a	4.6 ab	182 a	161 ab

[z] Means were separated within columns by Tukey's HSD (P = 0.05).

1999 NC-140 Dwarf Apple

As part of the 1999 NC-140 Dwarf Apple Rootstock Trial, a planting of McIntosh on 11 rootstocks was established at the University of Massachusetts Cold Spring Orchard Research & Education Center. Trees in this trial have performed well (average 2008 yield of 51 kg per tree with 183-g average fruit size). The planting included six replications in a randomized-complete-block design. Means from 2008 (10^{th} and final growing season) are included in Tables 3 and 4.

At the end of the 2008 season, largest trees were on CG.4013, and the smallest were on M.9 NAKBT337, Supporter 1, Supporter 2, and Supporter 3 (Table 3). Trees on G.16 were smaller, but not significantly, than those on M.26 EMLA, and trees on CG5179, G.202, and

G.41 were larger, but not significantly, than those on M.26 EMLA. Cumulative suckering (1999-2008) was greatest from CG.4013 and CG.5179 and least from G.16N and M.26 EMLA.

All trees yielded well in 2008, and few differences in yield per tree existed. Trees on CG.4013 yielded more than those on M.9 NAKBT337, Supporter 1, and Supporter 3. All other trees yielded intermediate to the two groups. 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. Lowest yields were harvested from trees on G.16N, M.9 NAKBT337, and Supporter 1.

In 2008, rootstock did not affect yield efficiency, but cumulatively (2001-08), trees on Supporter 1 and Supporter 2 were significantly more yield efficient than those on G.16N. All other combinations had intermediate efficiency and were not significantly different from the least or most yield efficient.

In 2008, rootstock did not affect fruit weight. On average (2001-08), fruit were from trees on M.9 NAKBT337 were larger than those from trees on Supporter 2, with all other rootstocks resulting in intermediate fruit size.

Table 5. Trunk cross-sectional area, tree height, canopy spread, and root suckering in 2008 of McIntosh trees on several rootstocks in the Massachusetts planting of the 1999 NC-140 Semidwarf Apple Rootstock Trial. All values are least-squares means, adjusted for missing subclasses.[z]

Rootstock	Trunk cross-sectional area (cm^2)	Tree height (m)	Average canopy spread (m)	Root suckers (no./tree, 1999-2008)
CG.4814	45 b	2.7 b	3.7 b	34.5 b
CG.7707	54 b	2.6 b	3.6 b	8.2 b
G.30N	105 a	3.3 ab	4.3 ab	30.5 b
M.26 EMLA	50 b	2.9 ab	3.6 b	3.5 b
M.7 EMLA	121 a	3.5 a	4.6 a	104.3 a
Supporter 4	101 a	3.4 a	4.1 ab	18.4 b

[z] Means were separated within columns by Tukey's HSD (P = 0.05).

Table 6. Yield, yield efficiency, and fruit weight in 2008 of McIntosh trees on several rootstocks in the Massachusetts planting of the 1999 NC-140 Semidwarf Apple Rootstock Trial. All values are least-squares means, adjusted for missing subclasses.[z]

	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Fruit weight (g)	
Rootstock	2008	Cumulative (2001-08)	2008	Cumulative (2001-08)	2008	Average (2001-08)
CG.4814	51 cd	225 bc	1.1 a	5.0 a	194 a	175 a
CG.7707	56 bc	239 bc	1.1 a	4.5 ab	182 ab	168 ab
G.30N	78 ab	334 a	0.8 ab	3.2 cd	184 ab	167 ab
M.26 EMLA	33 d	182 c	0.7 b	3.6 bc	161 b	165 b
M.7 EMLA	80 a	290 ab	0.7 b	2.5 d	194 a	175 a
Supporter 4	59 abc	258 ab	0.6 b	2.7 d	193 a	172 ab

[z] Means were separated within columns by Tukey's HSD (P = 0.05).

1999 NC-140 Semidwarf Apple

As part of the 1999 NC-140 Semidwarf Apple Rootstock Trial, a planting of McIntosh on six rootstocks was established at the University of Massachusetts Cold Spring Orchard Research & Education Center. Trees in this trial have performed reasonable well (average 2008 yield of 60 kg per tree with 174-g average fruit size); however, leaning has been an issue with some. The planting included six replications in a randomized-complete-block design. Means from 2008 (10th and final growing season) are included in Tables 5 and 6.

At the end of the 2008 season, 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 (Table 5). Greatest cumulative (1999-2008) root suckering was observed from trees on M.7 EMLA (Table 5).

M.7 EMLA resulted in the greater yield per tree in 2008 than did M.26 EMLA, CG.4814, and CG.7707, with trees on G.30N and Supporter 4 yielding intermediately (Table 6). Cumulatively (2001-08), trees on G.30N yielded more than those on CG.4814, CG.7707, or M.26 EMLA, with trees on M.7 EMLA and Supporter 4 yielding intermediately and similar to both extremes (Table 6).

In 2008, trees on CG.4814 and those on CG.7707 were more yield efficient than those on M.26 EMLA, M.7

Table 7. Trunk cross-sectional area, suckering, yield, yield efficiency, and fruit weight in 2008 of Gala trees on several rootstocks in the Massachusetts planting of the 2002 NC-140 Apple Rootstock Trial. All values are least-squares means, adjusted for missing subclasses.[z]

Rootstock	Trunk cross-sectional area (cm^2)	Root suckers (no./tree, 2002-08)	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Fruit weight (g)	
			2008	Cumulative (2004-08)	2008	Cumulative (2004-08)	2008	Average (2004-08)
B.9 (Europe)	19.9 f	8.9 b	3.2 c	41 c	0.17 ab	2.0 ab	155 d	156 d
B.9 (Treco)	22.8 ef	5.7 b	6.9 bc	47 bc	0.30 ab	2.1 a	164 bcd	167 cd
M.26 EMLA	45.7 cd	2.0 b	17.4 ab	67 abc	0.38 a	1.5 bc	173 abcd	174 bcd
M.26 NAKB	57.4 bc	2.3 b	24.2 a	82 a	0.44 a	1.5 bc	184 ab	184 ab
M.9 Burgmer 756	45.1 cd	6.6 b	14.3 abc	69 ab	0.33 ab	1.5 bc	184 ab	184 ab
M.9 Nic 29	38.2 de	25.0 a	11.1 bc	60 abc	0.30 ab	1.6 abc	192 a	194 a
M.9 NAKBT337	38.0 de	7.9 b	15.2 ab	61 abc	0.41 a	1.6 abc	184 ab	186 ab
P.14	68.9 b	1.8 b	10.7 bc	66 abc	0.16 ab	0.9 cd	174 abcd	181 abc
PiAu51-11	58.3 bc	6.0 b	13.0 abc	49 bc	0.26 ab	0.9 cd	178 abc	183 abc
PiAu51-4	98.7 a	7.5 b	6.4 bc	62 abc	0.06 b	0.6 d	158 cd	172 bcd
Supporter 4	52.9 bcd	2.0 b	14.6 abc	56 abc	0.28 ab	1.1 cd	184 ab	181 abc

[z] Means were separated within columns by Tukey's HSD ($P = 0.05$).

EMLA, or Supporter 4 (Table 6). Cumulatively (2004-08), CG.4814 resulted in the most efficient trees, followed by those on CG.7707, M.26 EMLA, and G.30N (Table 6). Trees on M.7 EMLA and Supporter 4 were the least yield efficient.

Largest fruit in 2008 were harvested from trees on CG.4814, M.7 EMLA, and Supporter 4, and the smallest came from those on M.26 EMLA (Table 6). Others resulted in intermediate size. On average (2001-08), largest fruit were from trees on CG.4814 and M.7 EMLA, and the smallest were from trees on M.26 EMLA (Table 6).

2002 NC-140 Apple

As part of the 2002 NC-140 Apple Rootstock Trial, a planting of Gala on 11 rootstocks was established at the University of Massachusetts Cold Spring Orchard Research & Education Center. Trees are growing well in this irrigated block, but fruit set was lighter than expected prior to 2007 (average yields in 2006 of only 3 kg per tree with 157-g average fruit size). In 2007, fruit set was good and the trees performed well (average yields in 2007 of 38 kg per tree with 186-g average fruit size). In 2008, fruit set was again less than expected (average yields in 2007 of 12 kg per tree with 175-g average fruit size). The planting included seven replications in a randomized-complete-block design. Means from 2008 (7^{th} growing season) are included in Table 7.

After the 2008 growing season, trees with the largest TCA 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). Cumulative (2002-08) root suckering was significantly greater from M.9 Nic 29 than from all other rootstocks.

Greatest yields in 2008 and cumulatively (2004-08) were harvested from trees on M.26 NAKB. Lowest yields were harvested from trees on B.9 (Europe).

Yield efficiency in 2008 was greatest for trees on the two strains of B.9 and least for trees on PiAu51-4, with other rootstocks generally resulting in intermediate efficiency. Cumulatively (2004-08), the two B.9 strains resulted in the greatest yield efficiency, while PiAu51-4 resulted in the lowest.

Fruit size in 2008 was very good for Gala for trees on all rootstocks, averaging from 155 to 192g. M.9 Nic 29 resulted in the largest fruit, and B.9 (Europe) and PiAu51-4 resulted in the smallest. Average fruit size over the fruiting life of the planting (2004-08) was largest from trees on M.9 Nic 29 and smallest from trees on the two B.9 strains.

PUBLICATIONS

Referreed

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. 62:119-128.

Non-refereed

Autio, W., T. Robinson, B. Black, T. Bradshaw, J. Cline, R. Crassweller, C. Embree, E. Hoover, K. Kosola, J. Masabni, M. Parker, R. Perry, G. Reighard, J. 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. Robinson, B. Black, T. Bradshaw, J. Cline, R. Crassweller, C. Embree, E. Hoover, K. Kosola, J. Masabni, M. Parker, R. Perry, G. Reighard, J. 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., 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 Physiology Trial. Fruit Notes 72(1):14-17.

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. 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. 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.

In Press

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.

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.

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.