ANNUAL REPORT TO NC-140

Massachusetts
Agricultural Experiment Station

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

PROGRESS & PRINCIPAL ACCOMPLISHMENTS

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 in 1999. Trees in this trial have performed well (average 2007 yield of 50 kg per tree with 170-g average fruit size). The planting included six replications in a randomized-complete-block design. Means from 2009 (9th growing season) are included in Table 1.

At the end of the 2007 season, largest trees were on CG.4013 and G.202, and the smallest were on M.9 NAKBT337, Supporter 1, Supporter 2, and Supporter 3. Trees on G.16 were smaller, but not significantly smaller, than those on M.26 EMLA, and trees on CG5179 and on G.41 were larger, but not significantly larger, than those on M.26 EMLA. Cumulative suckering (1999-2007) was greatest from CG.4013 and CG.5179 and least from G.16N, M.26 EMLA, and Supporter 1.

All trees yielded well in 2007, and few differences in yield per tree existed. Trees on CG.4013 yielded more

Table 1. Trunk cross-sectional area, suckering, yield, yield efficiency, and fruit weight in 2007 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)	Root suckers (no./tree, 1999-2007)	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Fruit weight (g)	
			2007	Cumulative (2001-07)	2007	Cumulative (2001-07)	2007	Average (2001-07)
G.41	54.0 bcd	2.9 b	46.1 ab	183 bc	0.85 a	3.41 abc	180 a	167 ab
CG.4013	89.5 a	14.3 a	67.9 a	287 a	0.76 a	3.27 abc	176 ab	162 ab
CG.5179	60.4 bc	14.3 a	47.0 ab	232 ab	0.82 a	3.90 abc	169 ab	159 ab
G.202	65.5 ab	2.5 b	56.3 ab	233 ab	0.86 a	3.65 abc	177 ab	164 ab
G.16N	43.5 bcd	0.0 b	26.3 b	121 c	0.64 a	2.81 c	150 b	161 ab
G.16T	41.3 bcd	2.5 b	49.1 ab	161 bc	1.19 a	3.96 abc	156 ab	156 ab
M.26 EMLA	50.5 bcd	0.0 b	51.8 ab	157 bc	1.07 a	3.17 bc	170 ab	164 ab
M.9 NAKBT337	32.7 d	5.5 ab	32.2 b	112 c	1.07 a	3.53 abc	180 a	173 a
Supporter 1	31.3 d	0.2 b	36.2 b	139 c	1.17 a	4.40 ab	170 ab	162 ab
Supporter 2	35.8 d	1.7 b	37.0 b	157 bc	1.02 a	4.37 ab	169 ab	148 b
Supporter 3	40.5 cd	4.3 b	43.3 ab	179 bc	1.07 a	4.42 a	175 ab	158 ab

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

than those on G.16N, M.9 NAKBT337, Supporter 1, and Supporter 2. All other trees yielded intermediate to the two groups. Cumulatively (2001-07), 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, G.16T, M.26 EMLA, Supporter 2, and Supporter 3. Lowest yields were harvested from trees on G.16N, M.9 NAKBT337, and Supporter 1.

In 2007, rootstock did not affect yield efficiency, but cumulatively (2001-07), trees on Supporter 3 were significantly more yield efficient than those on G.16N or M.26 EMLA. Trees on Supporter 1 and Supporter 2 were also 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.

G.41 and M.9 NAKBT337 resulted in larger fruit in 2007 than did G.16N, and all other rootstocks resulted in intermediate size, not significantly different from either extreme. On average (2001-07), fruit from trees on M.9 NAKBT337 were larger than those from trees on Supporter 2, with all other rootstocks resulting in intermediate average fruit size.

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 in 1999. Trees in this trial have performed reasonable well (average 2007 yield of 50 kg per tree with 165-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 2007 (9th growing season) are included in Table 2.

At the end of the 2007 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. Greatest cumulative (1999-2007) root suckering was observed from trees on M.7 EMLA.

M.7 EMLA resulted in greater yield per tree in 2007 than did CG.4814, with trees on other rootstocks yielding intermediately and similar to both. Cumulatively (2001-07), trees on G.30N yielded more than those on CG.4814 or M.26 EMLA, with others yielding intermediately and similar to both extremes.

Rootstock did not affect yield efficiency in 2007, but cumulatively (2004-07), CG.4814 resulted in the most efficient trees, followed by those on CG.7707, M.26 EMLA, G.30N, and Supporter 4. Trees on M.7 EMLA were the least yield efficient.

Largest fruit in 2007 were harvested from trees on G.30N, and the smallest came from those on CG.7707. Others resulted in intermediate size. On average (2001-07), rootstock did not affect fruit size.

2002 NC-140 Apple

As part of the 2002 NC-140 Apple Rootstock Trial, a

Table 2. Trunk cross-sectional area, suckering, yield, yield efficiency, and fruit weight in 2007 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)	Root suckers (no./tree, 1999-2007)	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Fruit weight (g)	
			2007	Cumulative (2001-07)	2007	Cumulative (2001-07)	2007	Average (2001-07)
CG.4814	38.2 b	25.2 b	33.3 b	174 b	0.89 a	4.56 a	173 ab	170 a
CG.7707	46.0 b	5.6 b	41.5 ab	183 ab	0.90 a	4.01 ab	142 c	165 a
G.30N	85.8 a	17.3 b	51.1 ab	255 a	0.60 a	2.99 bcd	181 a	164 a
M.26 EMLA	43.1 b	3.2 b	50.0 ab	149 b	1.14 a	3.44 bc	159 bc	165 a
M.7 EMLA	98.8 a	73.8 a	68.1 a	210 ab	0.71 a	2.17 d	165 ab	169 a
Supporter 4	82.2 a	10.2 b	53.4 ab	197 ab	0.68 a	2.50 cd	172 ab	168 a

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

Table 3. Trunk cross-sectional area, suckering, yield, yield efficiency, and fruit weight in 2007 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 and for crop load in the case of 2007 fruit weight.[z]

Rootstock	Trunk cross-sectional area (cm^2)	Root suckers (no./tree, 2002-07)	Yield per tree (kg) 2007	Yield per tree (kg) Cumulative (2004-07)	Yield efficiency (kg/cm^2 TCA) 2007	Yield efficiency (kg/cm^2 TCA) Cumulative (2004-07)	Fruit weight (g) 2007	Fruit weight (g) Average (2004-07)
B.9 (Europe)	15.4 e	4.9 b	21.1 c	38.0 a	1.35 ab	2.40 a	176 cd	156 c
B.9 (Treco)	17.6 e	2.7 b	23.3 bc	40.3 a	1.33 ab	2.37 a	184 bcd	167 bc
M.26 EMLA	34.3 bcd	1.5 b	38.7 abc	48.9 a	1.13 abc	1.43 bc	184 bcd	174 abc
M.26 NAKB	41.9 bc	1.4 b	43.4 a	58.3 a	1.06 abc	1.48 bc	194 abc	185 ab
M.9 Burgmer 756	32.3 cd	3.9 b	46.4 a	55.2 a	1.40 a	1.68 ab	197 ab	184 ab
M.9 Nic 29	28.0 d	17.3 a	37.5 abc	48.9 a	1.32 ab	1.72 ab	207 a	194 a
M.9 NAKBT337	28.2 d	4.3 b	39.6 ab	46.1 a	1.40 a	1.63 b	198 ab	187 ab
P.14	47.9 b	0.1 b	48.9 a	55.2 a	1.01 bcd	1.13 bc	180 bcd	181 ab
PiAu51-11	40.4 bcd	3.0 b	31.5 abc	36.4 a	0.83 cd	0.95 bc	181 bcd	186 ab
PiAu51-4	66.2 a	3.0 b	45.2 a	55.9 a	0.68 d	0.84 c	164 d	173 abc
Supporter 4	38.0 bcd	1.0 b	38.9 abc	41.9 a	1.04 bcd	1.12 bc	182 bcd	180 abc

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

planting of Gala on 11 rootstocks was established at the University of Massachusetts Cold Spring Orchard Research & Education Center in 2002. 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) The planting included seven replications in a randomized-complete-block design. Means from 2007 (6th growing season) are included in Table 3.

After the 2007 growing season, trees with the largest TCA were on PiAu51-4, followed in decreasing size by those on P.14, M.26 NAKB, PiAu51-11, Supporter 4, M.26 EMLA, M.9 Burgmer 756, M.9 NAKBT337, M.9 Nic 29, B.9 (Treco), and B.9 (Europe). Cumulative (2002-06) root suckering was significantly greater from M.9 Nic 29 than from all other rootstocks.

Largest yields in 2007 were harvested from trees on M.26 NAKB, M.9 Burgmer 756, P.14, and PiAu51-4. Lowest yields were harvested from the two B.9 strains. Other rootstocks resulted in intermediate yields. Cumulatively (2004-07), rootstock did not affect yield per tree.

Yield efficiency in 2007 was greatest for trees on M.9 Burgmer 756 and M.9 NAKBT337 and least for trees on PiAu51-11 and PiAu51-4, with other rootstocks generally resulting in intermediate efficiency. Cumulatively (2004-07), the two B.9 strains resulted in the greatest yield efficiency, while PiAu51-4 resulted in the lowest.

Fruit size in 2007 was very good for Gala on all rootstocks, averaging from 164 to 207g. The M.9 strains 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 (2004-07) was largest from trees on M.9 NAKBT337 and smallest from trees on the two B.9 strains.

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 in 2003. 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. The

Table 4. Trunk cross-sectional area, suckering, yield, yield efficiency, and average crop load in 2007 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, 2003-07)	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Crop load (2007, no./ cm^2 TCA)
			2007	Cumulative (2006-07)	2007	Cumulative (2006-07)	
G.16	15.9 a	0.0 a	19.4 a	25.1 a	1.25 a	1.60 a	7.8 a
M.26 EMLA	19.8 a	0.0 a	25.2 a	29.3 a	1.36 a	1.46 a	7.3 a
M.9 NAKBT337	11.3 b	0.4 a	17.1 a	21.7 a	1.54 a	1.95 a	8.5 a

planting includes ten trees of each rootstock in a completely random design. Means from 2007 (5th growing season) are included in Table 4 and Figures 1, 2, and 3.

At the end of the 2007 growing season, TCA of trees on G.16 and M.26 EMLA were significantly greater than that of trees on M.9 NAKBT337 (Table 4). Rootstock did not affect root suckering (2003-07), yield per tree (2007 or cumulative), yield efficiency (2007 or cumulative), or crop load (since they were adjusted) (Table 4).

The purpose of this trial was to determine if crop load and rootstock interacted to affect tree physiology. Crop load and rootstock did not interact significantly to affect trunk growth (Figure 1). Incremental growth in 2007 declined with increasing crop load and was greatest for trees on M.26 EMLA. Trees on M.9 NAKBT337 and on G.16 were similar. When presented as a percent of TCA at the end of 2006, trunk growth was similar for trees on M.26 EMLA and M.9 NAKBT337 and lower for trees on G.16.

Fruit characteristics also were measured in 2007 (Figure 2). Fruit size was negatively related to crop load, declining from an average of approximately 220g at 3 fruit/cm^2 TCA to 140g at 14 fruit/cm^2 TCA. Crop load did not interact with rootstock, however. M.9 NAKBT337 resulted in the largest fruit and G.16 and M.26 EMLA resulted in smaller and similarly sized fruit.

Flesh firmness declined with time and was negatively affected by crop load (Figure 2). Rootstock effects on firmness were nonsignificant, but rootstock interacted with crop load. Specifically, the impact of crop load on fruit from trees on M.9 NAKBT337 was variable but was more consistently negative with trees on M.26 EMLA and on G.16. The general trends noticed for firmness are particularly interesting, since fruit from trees with a greater crop load were smaller and ripen later, two conditions where increased firmness would be expected.

Soluble solids concentration was affected by rootstock, with M.9 NAKBT337 resulting in the highest concentration and M.26 EMLA resulting in the lowest (Figure 2). Crop load was negatively related to soluble solids concentration, but it also interacted significantly with rootstock. As with flesh firmness, the negative effect was most consistent with fruit from trees on M.26 EMLA and on G.16. Soluble solids concentration of fruit from trees on M.9 NAKBT337 was negatively affected by increasing crop load, possibly to a lesser degree than the other rootstocks, but the effect also was more variable. The general results with soluble solids concentration followed what would be expected relative to effects of crop load and rootstock on ripening, with the ripest fruit having the greatest concentrations.

Starch contents also were affected by rootstock, with fruit from trees on G.16 and on M.26 EMLA having the lowest contents (highest index values) and those from trees on M.9 NAKBT337 having the highest content (lowest index values) (Figure 2). Crop load was negatively related to starch content (positively related to index values), and crop load did not interact significantly with rootstock. It is interesting to note that the lowest starch contents, normally associated with the ripest fruit, were measured at the highest crop loads. Clearly, competition for carbohydrates reduced starch concentration in fruit at the high crop loads. Likely, the low soluble solids concentrations also seen at high crop loads were as much related to low starch levels as delayed ripening.

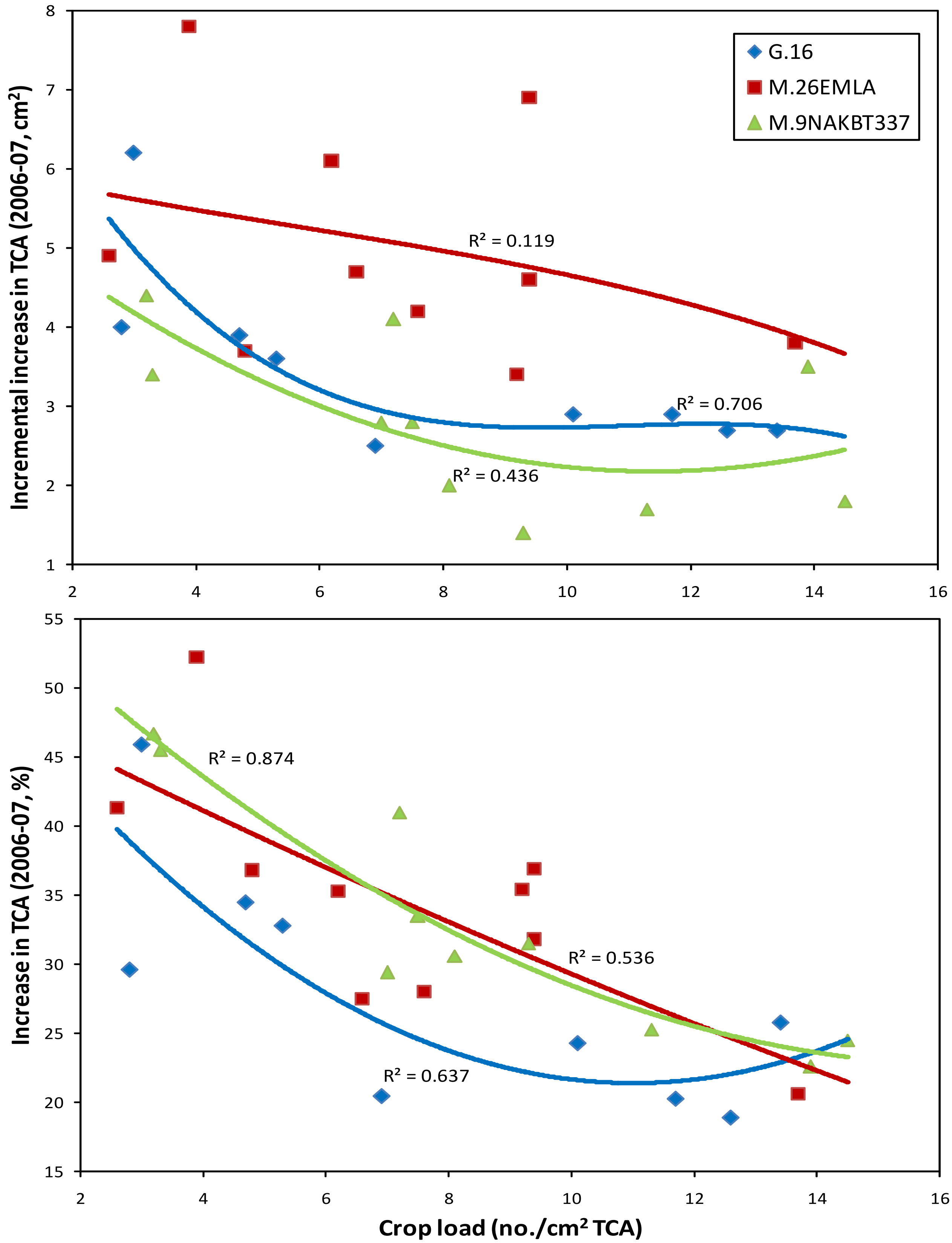

Figure 1. Effects of crop load and rootstock on trunk growth in 2007, expressed as the incremental and percentage increase in trunk cross-sectional area, of Gibson Golden Delicious trees in the 2003 Apple Rootstock Physiology Trial.

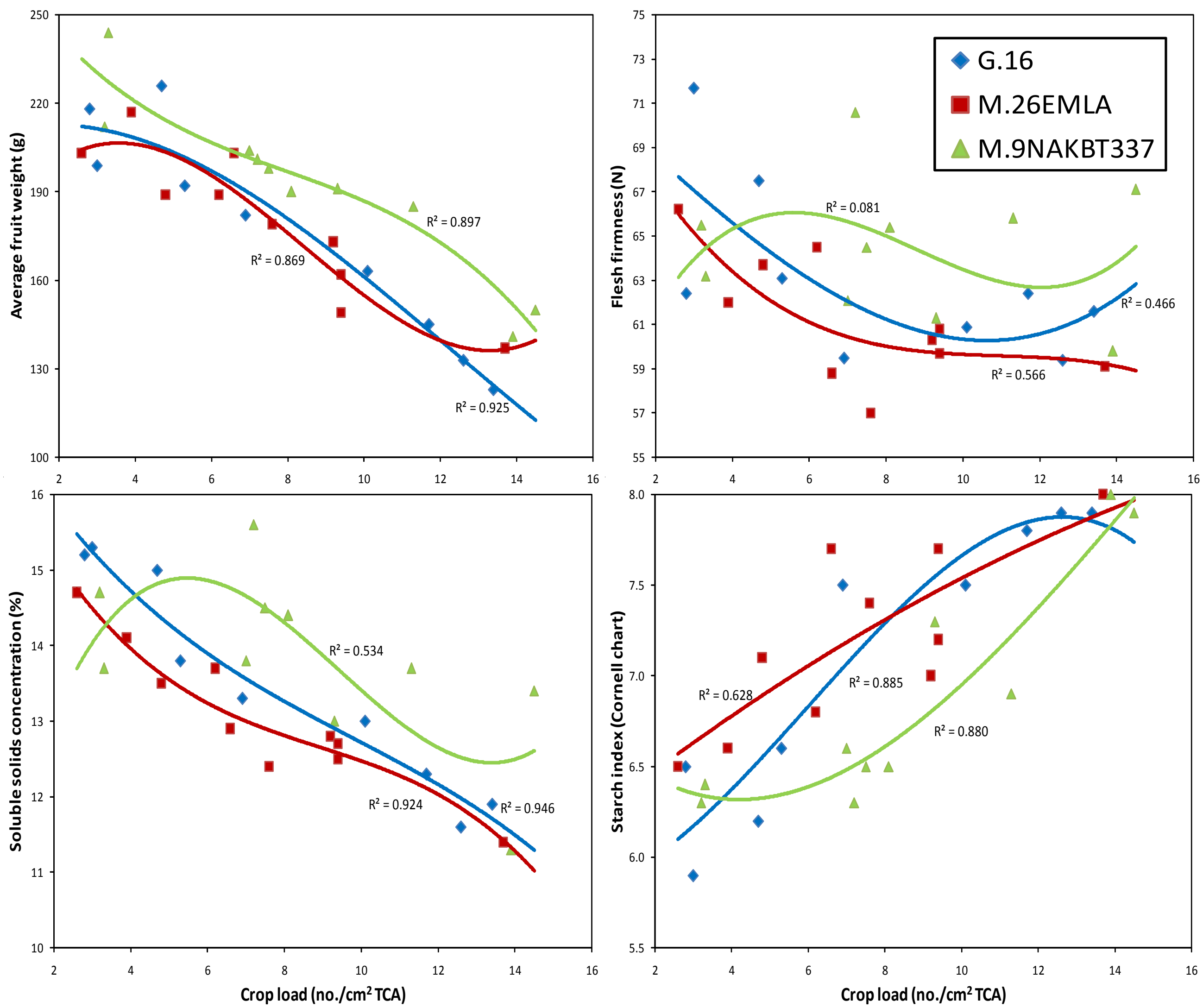

Figure 2. Effects of rootstock and crop load on size, flesh firmness, soluble solids concentration, and starch breakdown of fruit from Gibson Golden Delicious trees in the 2003 Apple Rootstock Physiology Trial.

Internal ethylene concentrations more accurately assess ripening than do flesh firmness, soluble solids concentration, or starch content, particularly in an experiment where treatments affect the latter measurements outside of their effects on ripening. Overall, ethylene concentrations were similar in the core cavity of fruit from trees on G.16 and M.9 NAKBT337 (Figure 3). The concentration was lower in fruit from trees on M.26, suggesting that these fruit were less ripe than those from trees on G.16 or M.9 NAKBT337. The negative effects of crop load on internal ethylene concentration were pronounced, confirming other work showing a negative relationship between crop load and ripening. Also, crop load and rootstock interacted significantly. The relationship between crop load and internal ethylene were consistent and dramatically negative for G.16 and M.26 EMLA. The relationship was more variable and less pronounced for M.9 NAKBT337. Using the date when fruit reached an average log ethylene of zero, the date of ripening can be compared. Crop load had a pronounced effect, delaying ripening by as much as 3 weeks from light set to heavy set. Crops load and rootstock did not interact significantly. On average, fruit from trees on M.9 NAKBT337 ripened 1.2 days before those from trees on G.16, and fruit from trees on M.26 EMLA ripening 3.8 days later than those on G.16.

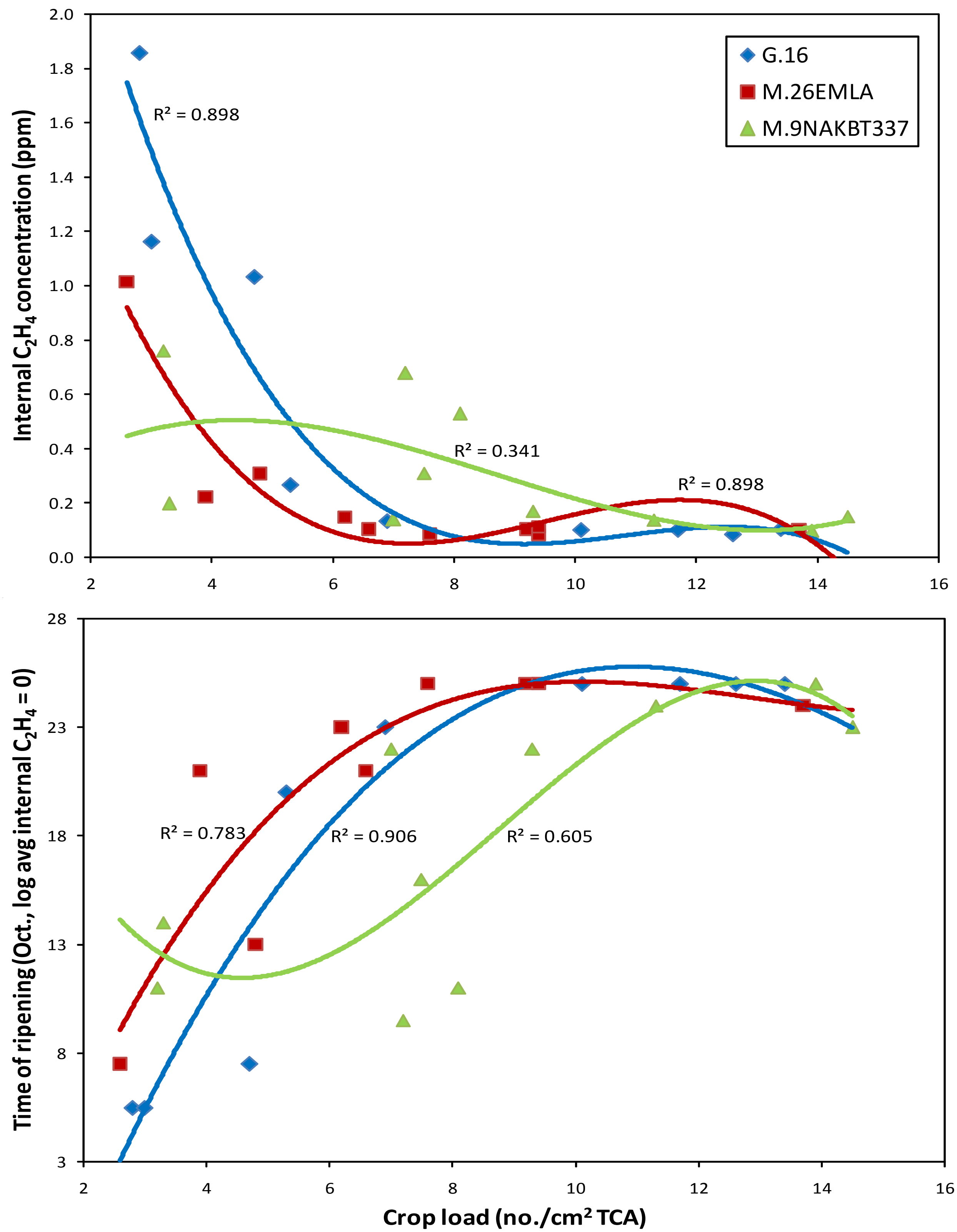

Figure 2. Effects of rootstock and crop load on the internal ethylene concentration and an estimate of the time of ripening of fruit from Gibson Golden Delicious trees in the 2003 Apple Rootstock Physiology Trial.

USEFULNESS OF FINDINGS

We have further refined our understanding of the characteristics of several rootstocks grown under Massachusetts conditions with McIntosh, Gala, Golden Delicious, and Cameo as apple scion cultivars. Several rootstocks in the older plantings show great promise for potential commercial adoption.

In addition to the economic benefits associated with the greater yield efficiency and fruit size of trees on some of these dwarfing rootstocks, significant benefits are realized by growers in Massachusetts selling fruit using pick-your-own techniques. These fully dwarf trees seem particularly suited to pick-your-own marketing, providing for significantly less loss due to fruit drop and poor quality. Further, significantly less pesticide is required to treat dwarf trees (low tree volume).

WORK PLANNED FOR 2007

All existing plantings will be maintained in 2008. Final reports of the 1995 Massachusetts-Maine-Nova Scotia Rootstock Trial and the 1996 McIntosh Rootstock Trial will be developed for publication.

PUBLICATIONS

Refereed Journal Articles

Autio, W.R., T.L. Robinson, B.H. Barritt, J.A. Cline, R.M. Crassweller, C.G. Embree, D.C. Ferree, M.E. Garcia, G.M. Greene, E.E. Hoover, R.S. Johnson, K. Kosola, J. Masabni, M.L. Parker, R.L. Perry, G.L. Reighard, S.D. Seeley, and M. Warmund. 2007. Early performance of ‘Fuji’ and ‘McIntosh’ apple trees on several dwarf rootstocks in the 1999 NC-140 Rootstock Trial. Acta Hort. 732:119-125.

Autio, W.R., T.L. Robinson, B.H. Barritt, J.A. Cline, R.M. Crassweller, C.G. Embree, D.C. Ferree, M.E. Garcia, G.M. Greene, E.E. Hoover, R.S. Johnson, K. Kosola, J. Masabni, M.L. Parker, R.L. Perry, G.L. Reighard, S.D. Seeley, and M. Warmund. 2007. Early performance of ‘Fuji’ and ‘McIntosh’ apple trees on several semidwarf rootstocks in the 1999 NC-140 Rootstock Trial. Acta Hort.732:127-133.

Robinson, T., L. Anderson, W. Autio, B. Barritt, J. Cline, R. Crassweller, W. Cowgill, C. Embree, D. Ferree, E. Garcia, G. Greene, C. Hampson, K. Kosola, M. Parker, R. Perry, T. Roper, and M. Warmund. 2007. A multi-location comparison of Geneva 16, Geneva 41, and M.9 apple rootstocks across North America. Acta Hort. 732:59-65.

Reighard, G., R. Andersen, J. Anderson, W. Autio, T. Beckman, T. Baker, R. Belding, G. Brown, P. Byers, W. Cowgill, D. Deyton, E. Durner, A. Erb, D. Ferree, A Gaus, R. Godin, R. Hayden, P. Hirst, S. Kadir, M. Kaps, H. Larsen, T. Lindstrom, N. Miles, F. Morrison, S. Myers, D. Ouelette, C. Rom, W. Shane, B. Taylor, K. Taylor, C. Walsh, and M. Warmund. 2007. Growth and yield of ‘Redhaven’ peach on nineteen rootstocks at twenty North American locations. Acta Hort. 732:271-278.

Non-refereed Journal Articles

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.

Robinson, T., L. Anderson, W. Autio, B. Barritt, J. Cline, W. Cowgill, R. Crassweller, C. Embree, D. Ferree, E. Garcia, G. Greene, C. Hampson, K. Kosola, M. Parker, R. Perry, T. Roper, and M. Warmund. 2007. Performance of Geneva 16, Geneva 41 and M.9 apple rootstocks in the 1998 NC-140 Apple Rootstock Trial. Compact Fruit Tree 40: in press.