ANNUAL REPORT TO NC-140

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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). In 2009, trees performed well, with average yields of 57 kg per tree with 162-g average fruit size. Although yields suggest a biennial-bearing pattern, trees have bloomed well in the last two off seasons. The planting includes seven replications in a randomized-complete-block design. Means from 2009 (8th growing season) are included in Table 1.

After the 2009 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 NAKBT337, M.9 Nic 29, B.9 (North America), and B.9 (Europe). Cumulative (2002-09) root suckering was significantly greater from M.9 Nic 29 than from all other rootstocks.

Greatest yields in 2009 and cumulatively (2004-08) were harvested from trees on PiAu 51-4. Cumulative yields from trees on M.26 NAKB were also high. Lowest yields in 2009 and cumulatively were from trees on the two strains of B.9.

Yield efficiency in 2009 was greatest for trees on B.9 (North America), M.9 Burgmer 756, and M.9 NAKBT337 and least for trees on PiAu51-4. Cumulatively (2004-09), B.9 (North America) resulted in the greatest yield efficiency, while PiAu51-4 resulted in the lowest.

Fruit size in 2009 was good for trees on all rootstocks, averaging from 143 to 177g, with no significant differences

Table 1. Trunk cross-sectional area, suckering, yield, yield efficiency, and fruit weight in 2009 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 also for crop load in the case of 2009 fruit weight.[z]

Rootstock	Trunk cross-sectional area (cm^2)	Root suckers (no./tree, 2002-09)	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Fruit weight (g)	
			2009	Cumulative (2004-09)	2009	Cumulative (2004-09)	2009	Average (2004-09)
B.9 (Europe)	22 f	11 b	24 d	65 d	1.1 abc	2.9 ab	167 a	156 b
B.9 (North America)	25 ef	8 b	33 cd	81 cd	1.3 a	3.2 a	174 a	165 ab
M.26 EMLA	53 cd	3 b	56 b	122 abc	1.1 abc	2.3 bcd	163 a	170 ab
M.26 NAKB	65 bcd	3 b	67 b	149 a	1.0 bcd	2.4 bc	162 a	173 ab
M.9 Burgmer 756	51 cd	8 b	69 ab	138 ab	1.3 a	2.7 ab	173 a	170 ab
M.9 Nic 29	43 def	30 a	53 bc	113 abc	1.2 ab	2.6 ab	168 a	175 a
M.9 NAKBT337	44 de	11 b	56 b	118 abc	1.3 a	2.7 ab	177 a	178 a
P.14	82 b	3 b	71 ab	137 ab	0.9 cd	1.6 de	153 a	172 ab
PiAu51-11	71 bc	10 b	56 b	105 bcd	0.9 cd	1.6 de	151 a	169 ab
PiAu51-4	120 a	10 b	90 a	152 a	0.7 d	1.3 e	143 a	165 ab
Supporter 4	64 bcd	3 b	55 bc	111 abc	0.9 cd	1.8 cd	151 a	170 ab

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

among trees on the different rootstocks. Average fruit size over the fruiting life of the planting (2004-09) was largest from trees on M.9 NAKBT337 and those on M.9 Nic 29 and smallest from trees on B.9 (Europe).

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). In 2009, crop load was again adjusted per the experimental protocol, and fruit characteristics were assessed at the end of the season. Because of tree size and the amount of work required to count whole trees, three limbs were selected, and initial set was determined only on those limbs. Set was adjusted

Table 2. Trunk cross-sectional area, crop load, yield, yield efficiency, and fruit size in 2009 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)	Crop load (no./cm^2 TCA)	Yield per tree (kg)		Yield efficiency (kg/cm^2 TCA)		Fruit weight (g)	
			2009	Cumulative (2004-09)	2009	Cumulative (2004-09)	2009	Average (2004-09)
G.16	27 b	11.0 a	36 b	68 b	1.3 b	2.5 b	134 a	147 a
M.26 EMLA	36 a	9.7 a	51 a	87 a	1.4 ab	2.4 b	157 a	159 a
M.9 NAKBT337	21 b	11.8 a	35 b	63 b	1.6 a	3.0 a	156 a	165 a

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

Table 3. Trunk growth and fruit characteristics in 2009 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 increase (cm^2)	Trunk cross-sectional area increase (%)	Fruit weight (g)	Flesh firmness (N)	Soluble solids (%)	Starch index (Cornell scale)	Internal ethylene concentration (ppm)	Date of ripening (October date when ppm ethylene = 1)
No covariate:								
G.16	3.4 b	15.7 a	134 a	67 a	10.5 a	7.8 a	2.6 a	12.1 a
M.26 EMLA	4.5 a	16.0 a	157 a	65 a	10.7 a	7.7 a	3.6 a	10.7 a
M.9 NAKBT337	2.3 c	14.2 a	156 a	66 a	11.1 a	7.6 a	5.4 a	11.8 a
Adjusted for crop load:								
G.16	3.5 b	15.9 a	148 b	67 a	10.5 ab	7.8 a	3.1 b	10.9 a
M.26 EMLA	4.4 a	15.5 a	150 b	65 a	10.4 b	7.8 a	5.4 a	12.1 a
M.9 NAKBT337	2.4 c	14.7 a	173 a	65 a	11.4 a	7.6 b	5.3 a	11.2 a
Covariate structure	load	load	load	load(t)	load	load	load(t) $load^2$(t)	load(t) $load^2$(t)

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

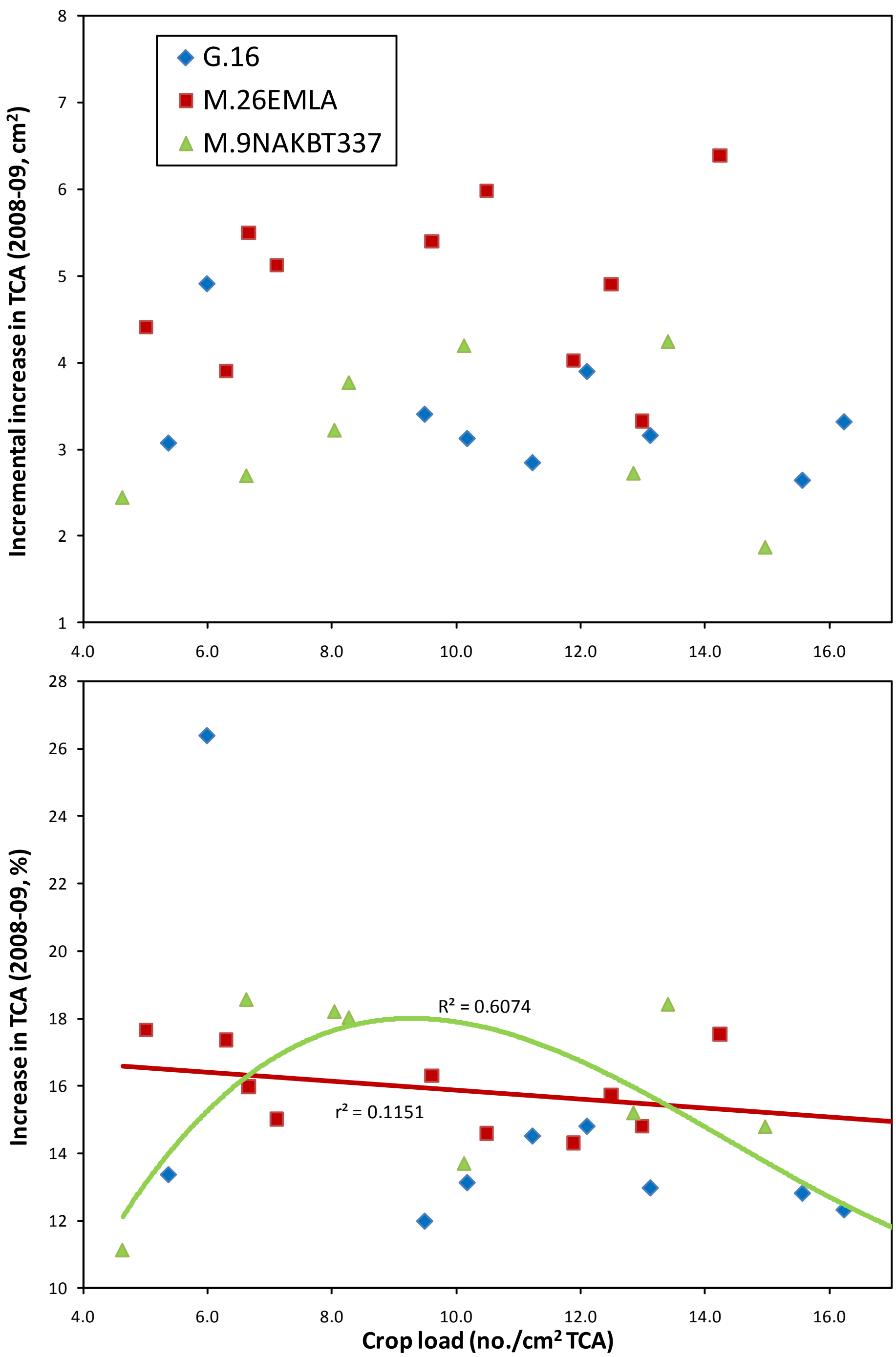

Figure 1. Effects of crop load on trunk growth of Gibson Golden Delicious trees on G.16, M.26 EMLA, or M.9 NAKBT337 in the Massachusetts planting of the 2003 NC-140 Apple Rootstock Physiology Trial.

on those three limbs based on actual counts and limb cross-sectional area. The rest of the tree was adjusted to approximate the set on those three limbs. In practice, this approach was much easier than counting the entire tree, but on average, we did not attain as low a fruit set as desired on most trees. The planting included ten trees of each rootstock in a completely random design. Means from 2009 (7th growing season) are included in Tables 2 and 3 and Figures 1-7.

At the end of the 2009 growing season, TCA of trees on M.26 EMLA was significantly greater than that of trees on G.16 and those on M.9 NAKBT337 (Table 2). Yield per tree (2009 or cumulatively) was greatest from trees on M.26 EMLA (Table 1). Yield efficiency in 2009 was greater for trees on M.9 NAKBT337 than for those on G.16, and cumulatively (2004-09), yield efficiency was greater for trees on M.9 NAKBT337 than those on either G.16 or M.26 EMLA. Fruit size in 2009 and on average (2006-09) were not different among rootstocks, but the experimental protocol established a great deal of variance if crop load is not accounted for in the analysis (Table 1).

The purpose of this trial was to determine if crop load and rootstock interacted to affect tree physiology. Incremental growth was one aspect of tree performance affected by crop load; however, the intensity of the effect was not as great as 2 years ago when crop load was previously adjusted. As expected, increasing crop load reduced growth assessed either as unit of TCA (Table 3, Figure 1) or percentage change in TCA (Table 3, Figure 2). In neither case did the crop load effect change with rootstock. Regarding the rootstock effect, all grew at about the same percentage rate (Table 3).

Fruit weight was negatively affected by increasing crop load, and when load was accounted for, M.9 NAKBT337 resulted in the largest fruit (Table 3). The crop load effect did not change with rootstock (Table 3, Figure 2).

Fruit ripening was also assessed with three samples of 10 fruit per tree (October 5, 13, and 19, 2009). Internal ethylene

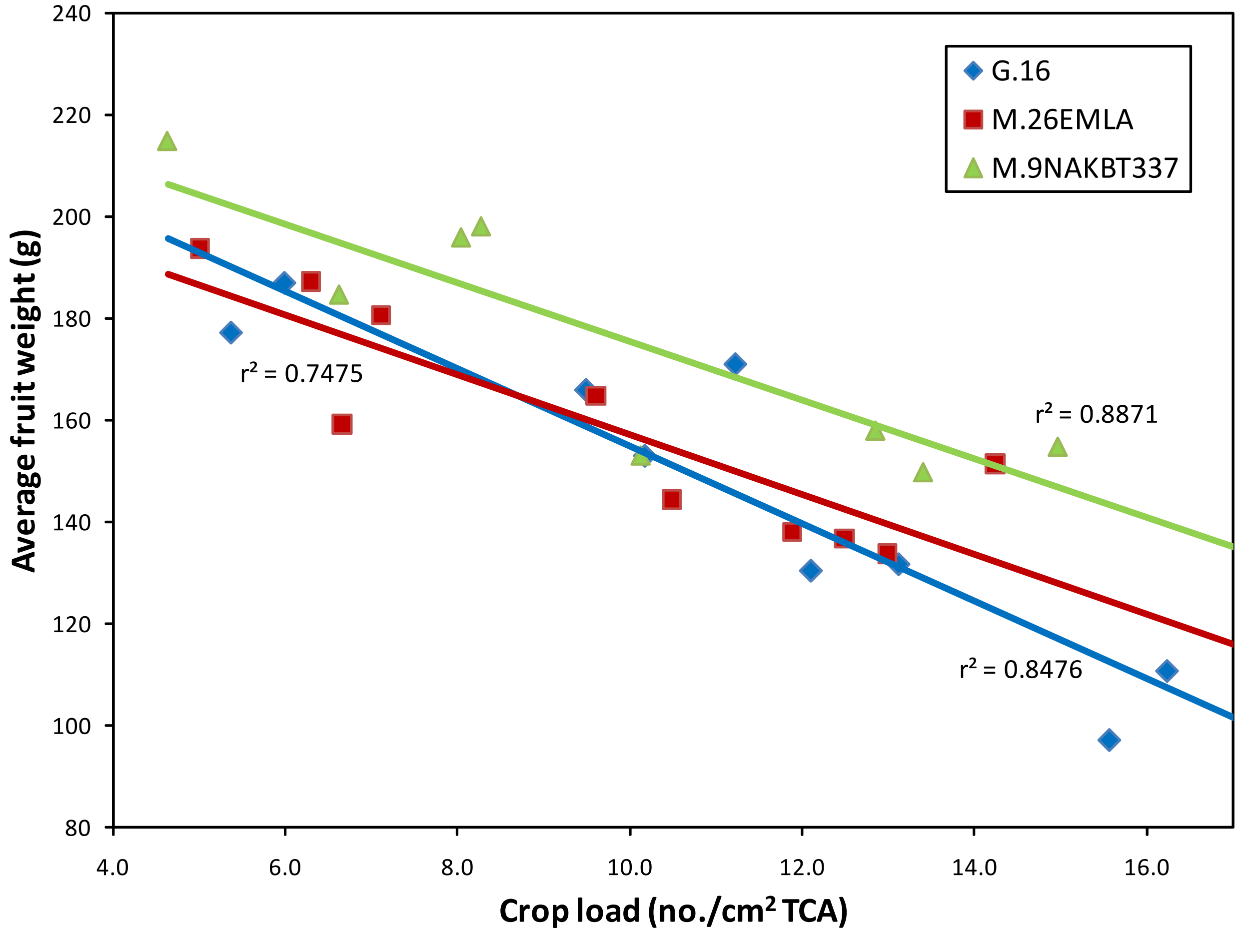

Figure 2. Effects of crop load on size of fruit from Gibson Golden Delicious trees on G.16, M.26 EMLA, or M.9 NAKBT337 in the Massachusetts planting of the 2003 NC-140 Apple Rootstock Physiology Trial.

concentration, flesh firmness (2 punctures per fruit), soluble solids concentration, and starch index level were assessed on each fruit immediately following sampling. Ethylene is the most accurate representation of the progress of ripening. Using the date when the average fruit on a tree reach 1 ppm (actually when the average of the log ppm = 0), we can compare the time of ripening (Table 3, Figure 3). Overall, there was no significant rootstock effect on the time of ripening, but crop load affected it, and the relationship changed with rootstock (Figure 3). The delay in ripening caused by increasing crop load was not significant for trees on M.9 NAKBT337. For those on M.26 EMLA and on G.16, the effect of crop load was similar. Internal ethylene concentration itself showed a similar response, with differences in the crop load effect among the rootstocks (Table 3, Figure 4). Trees on M.9 NAKBT337 generally were not responsive to increasing crop loads; whereas, increasing crop loads resulted in lower internal ethylene levels of fruit from trees on the other two rootstocks, suggesting a delay in ripening.

Firmness also responded to crop load, and the

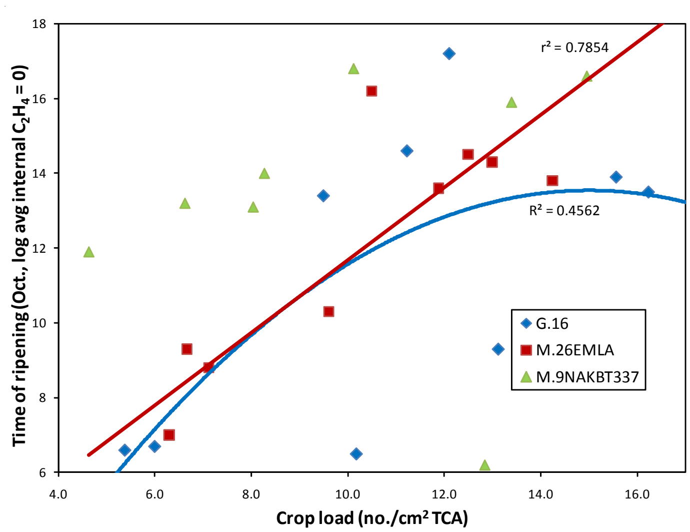

Figure 3. Effects of crop load on the time of ripening of fruit from Gibson Golden Delicious trees on G.16, M.26 EMLA, or M.9 NAKBT337 in the Massachusetts planting of the 2003 NC-140 Apple Rootstock Physiology Trial.

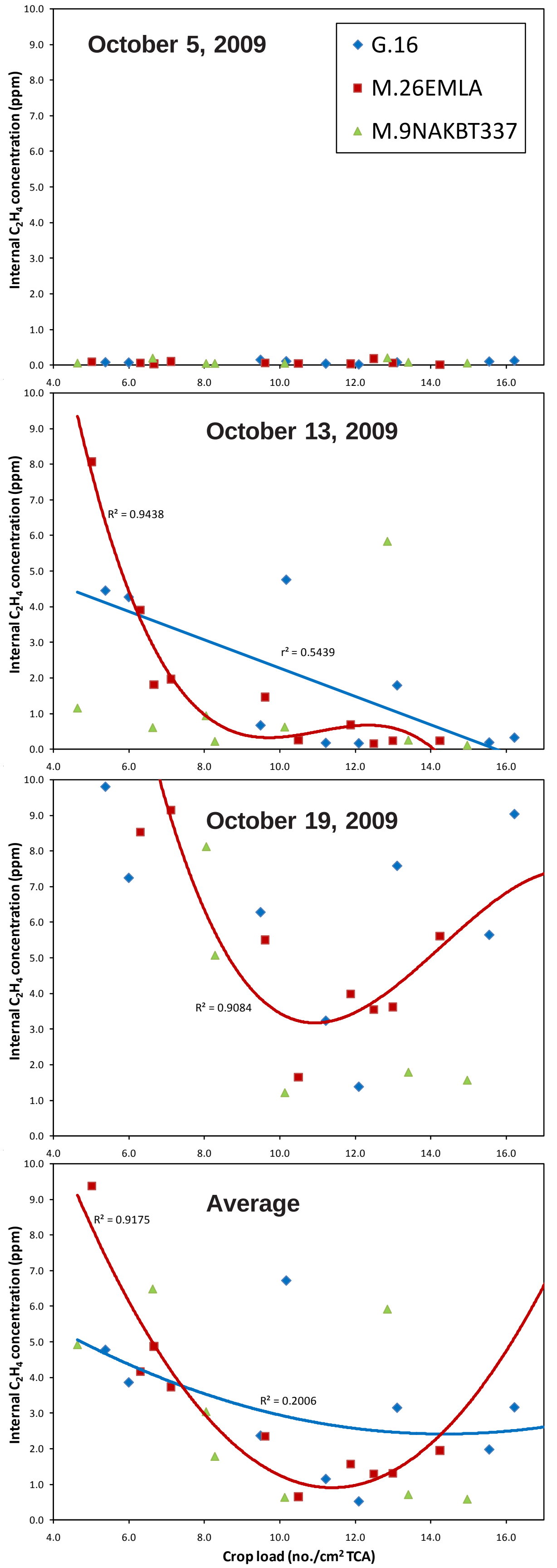

Figure 4. Effects of crop load on internal ethylene concentration of Gibson Golden Delicious fruit.

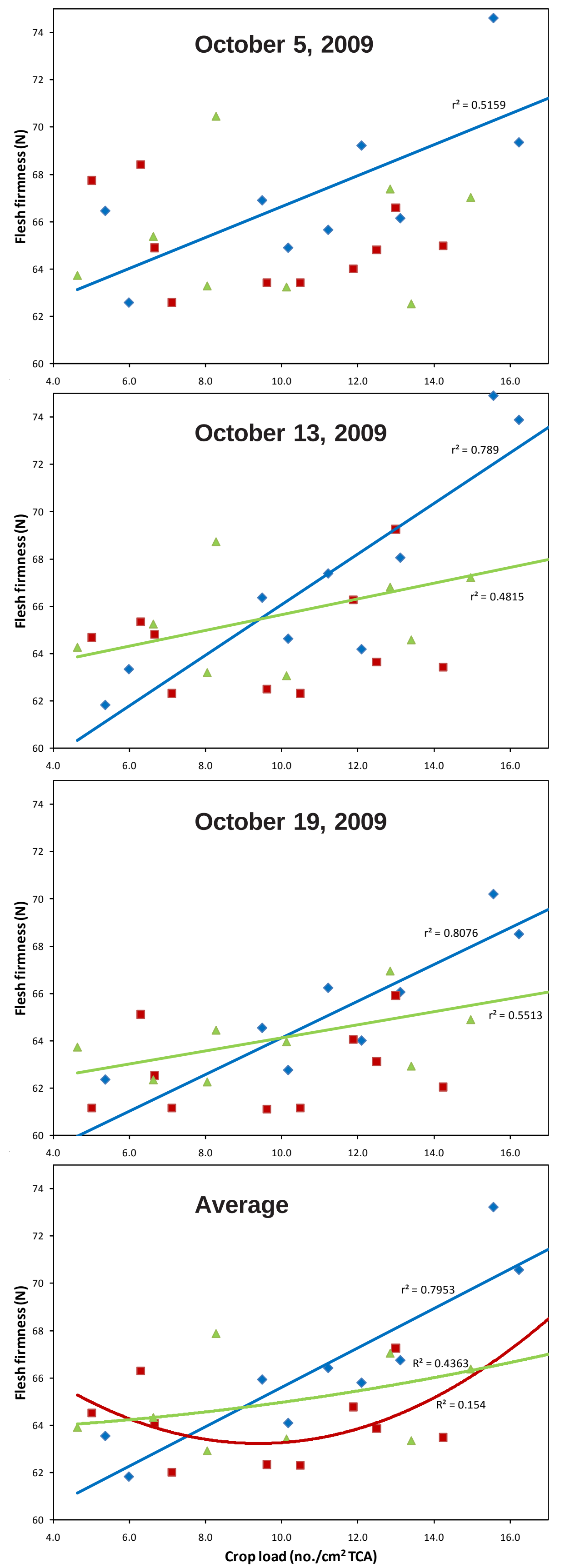

Figure 5. Effects of crop load on flesh firmness of Gibson Golden Delicious fruit.

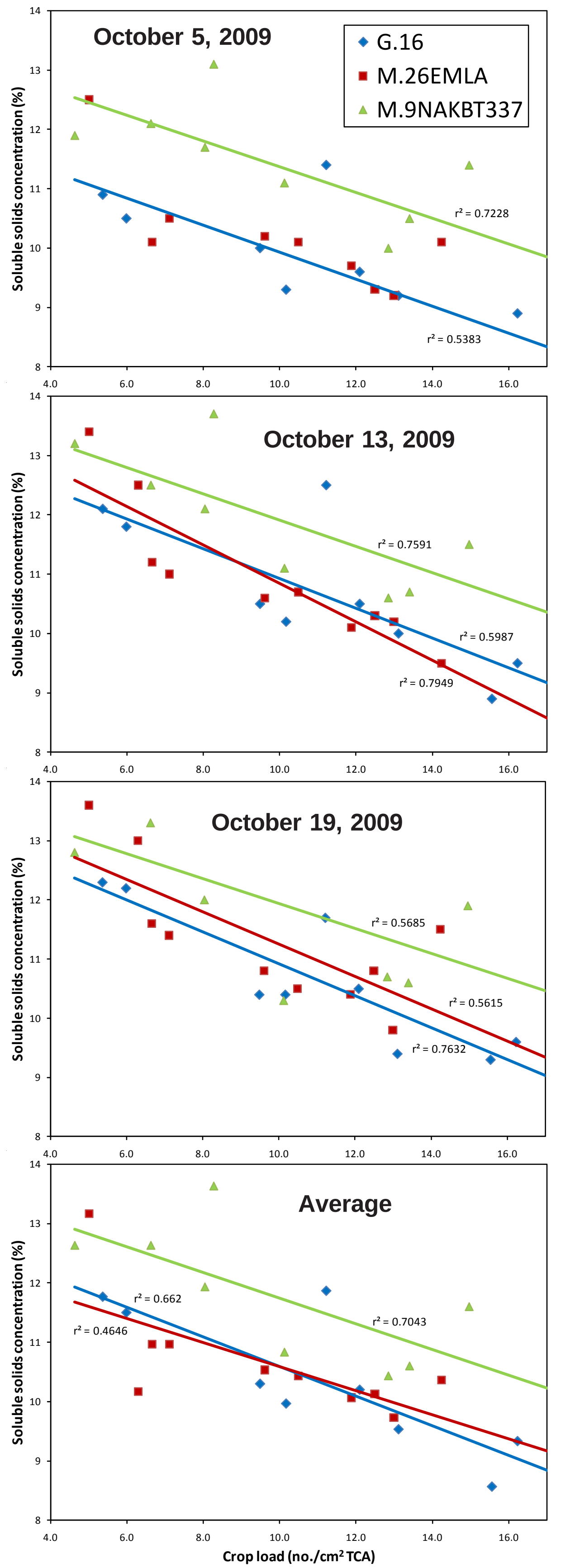

Figure 6. Effects of crop load on soluble solids concentration of Gibson Golden Delicious fruit.

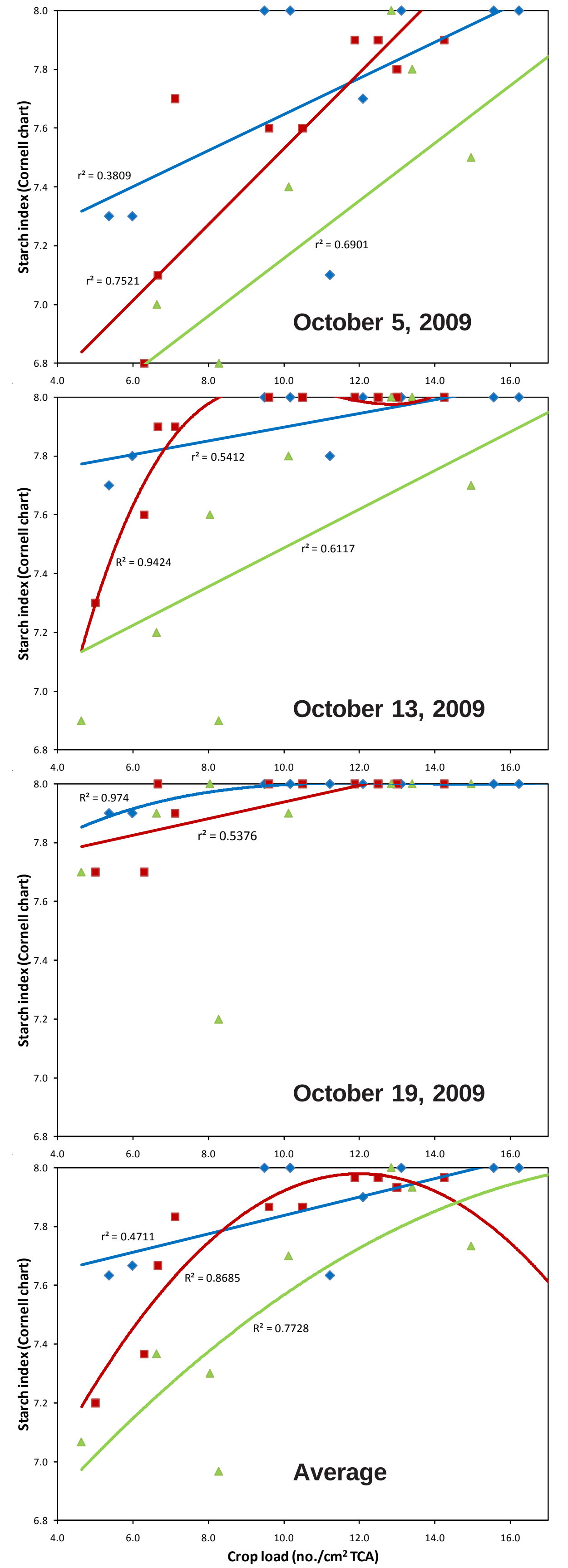

Figure 7. Effects of crop load on starch index value (Cornell chart) of Gibson Golden Delicious fruit.

Table 4. Trunk size and growth in 2009 of Redhaven peach trees in the 2009 NC-140 Peach Rootstock Trial.[z]

	Trunk cross-sectional area (cm^2)		Incremental growth in 2009	
Rootstock	At planting	End of season	cm^2	%
Atlas	1.1 defg	6.4 ab	5.3 abc	503 b
Brights Hybrid 5	1.2 defg	6.1 abc	4.9 bc	415 bc
Controller 5	1.1 defg	1.9 d	0.9 d	87 e
Guardian	0.9 fg	7.8 a	6.9 a	793 a
HBOK 10	1.4 def	7.0 ab	5.6 ab	401 bcd
HBOK 32	1.6 cd	7.4 ab	5.8 ab	355 bcd
KV010-123	1.2 defg	6.2 abc	5.0 abc	422 bc
KV010-127	1.1 defg	6.0 abc	5.0 abc	470 b
Krymsk 1	0.8 g	4.1 cd	3.3 c	413 bcd
Krymsk 86	1.0 efg	5.4 bc	4.4 bc	474 b
Lovell	1.0 efg	6.0 abc	5.0 abc	542 b
Mirobac	1.5 de	7.2 ab	5.7 ab	375 bcd
Prunus americana	3.2 a	7.6 a	4.4 bc	143 e
Penta	2.7 ab	7.9 a	5.3 ab	220 de
Viking	2.2 bc	7.7 a	5.5 ab	256 cde

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

effects of load varied with rootstock (Table 3, Figure 5). In general, the firmness effect was a response to fruit size, with the smaller fruit being firmer. Therefore, as crop load increased, fruit size decreased (Figure 3), and flesh firmness increased. This response was greatest for fruit from trees on G.16 (Figure 3).

Sugar and starch concentrations in the fruit normally change in a predictable way with maturation and ripening and are often good measures of the progress of ripening. In this experiment, however, they responded oppositely to what would be expected with regards to ripening. Specifically, as crop load increased, soluble solids concentration declined, and starch index value increased, even though ripening was delayed (Table 3, Figures 6 and 7). This effect was not altered by rootstock. Clearly, when crop load increased, trees were deprived of adequate energy to produce starch. These fruit initiated ripeing with very little starch available to break down into sugars, hence low soluble solids concentration and a high starch index value.

2009 NC-140 Peach

As part of the 2009 NC-140 Peach Rootstock Trial, a planting of Redhaven on 15 rootstocks was established at the University of Massachusetts Cold Spring Orchard Research & Education Center. Trees grew well in their first season. The planting includes eight replications in a randomized-complete-block design. Means from 2009 (1st growing season) are included in Table 4.

At the end of the 2009 season, trees on Penta, Guardian, Viking, and *Prunus americana* were the largest, and those on Controller 5 were the smallest. From planting to the end of the season, the fastest growing trees were on Guardian, and the slowest were on Controller 5 and *P. americana*.

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