An Update on the 2003 NC-140 Apple Rootstock Physiology Trial, 2009 Results

Wesley R. Autio, James S. Krupa, and Jon M. Clements
Department of Plant, Soil, & Insect Sciences, University of Massachusetts

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. The objective of this NC-140-coordinated trial was to determine if response to crop load varied with rootstock.

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, with trees of each rootstock ranging from a very light crop to a very heavy crop (results reported in *Fruit Notes*, Winter, 2007). In 2008, return bloom was assessed, and crop load of all trees was reduced to very light (results reported in *Fruit Notes*, 2008). In 2009, crop load was again adjusted from very light to very heavy for each rootstock, and fruit characteristics were assessed at the end of the season. Means from 2009 (7th growing season) are included in Tables 1 and 2 and Figures 1-8.

At the end of the 2009 growing season, trunk cross-sectional area (TCA) of trees on M.26 EMLA was significantly greater than that of trees on G.16 and those on M.9 NAKBT337 (Table 1, Figure 1). Yield per tree (2009 or cumulatively) was greatest from trees on M.26 EMLA (Table 1, Figure 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 (Table 1, Figure 1). Fruit size in 2009 and on average (2006-09) were not different among rootstocks, but the experimental protocol established a great deal of vari-

Table 1. 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) 2009	Yield per tree (kg) Cumulative (2004-09)	Yield efficiency (kg/cm^2 TCA) 2009	Yield efficiency (kg/cm^2 TCA) Cumulative (2004-09)	Fruit weight (g) 2009	Fruit weight (g) 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 within columns not followed by a common letter are significantly different at odds of 19 to 1 (Tukey's HSD, $P = 0.05$).

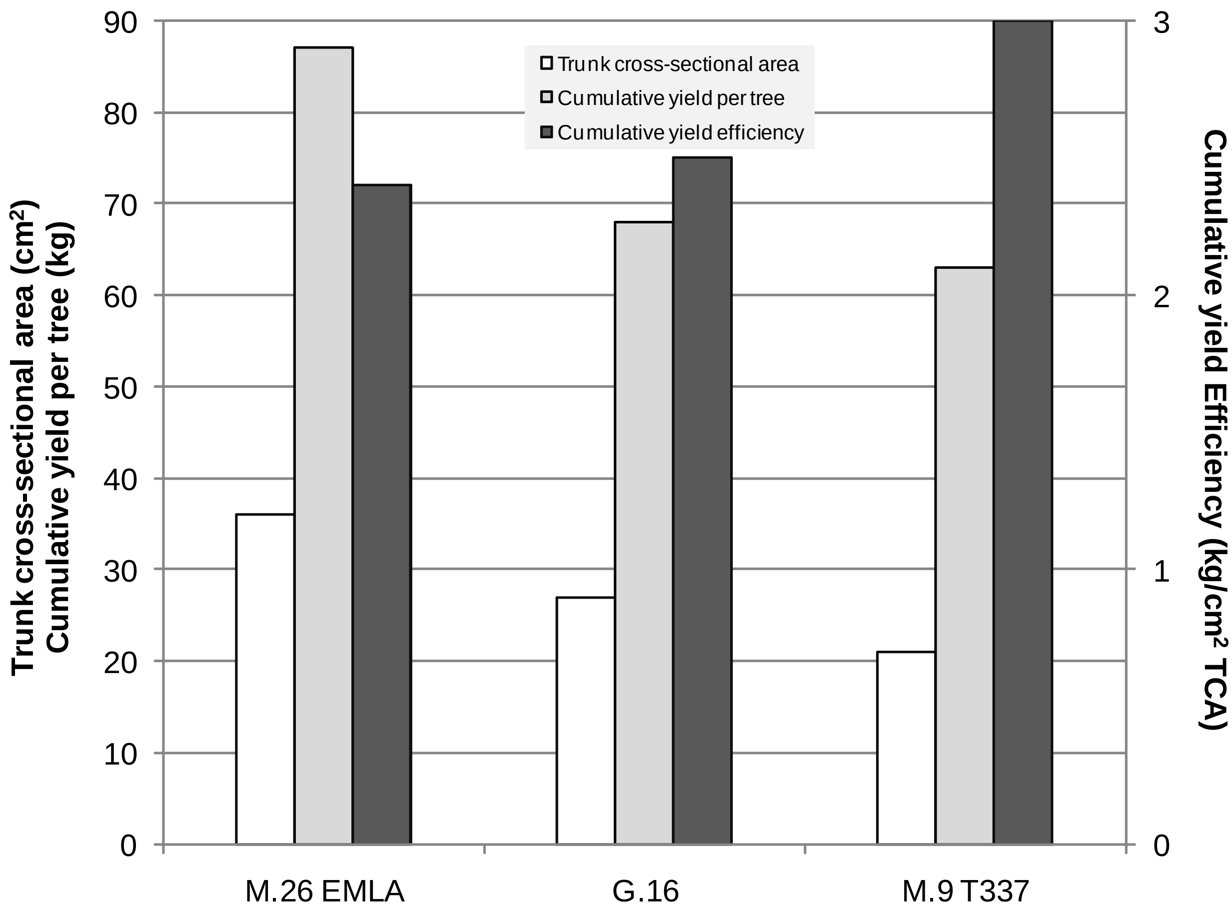

Figure 1. Relative tree size, cumulative yield, and cumulative yield efficiency of Gibson Golden Delicious in 2009 in the Massachusetts planing of the 2003 NC-140 Apple Rootstock Physiology Trial.

ance in crop load and thus fruit size (Table 1).

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 2, Figure 2) or percentage change in TCA (Table 2, Figure 3). In neither case did the crop load effect change with rootstock. Regarding the rootstock effect, all grew at about the same percentage rate (Table 2).

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

Fruit ripening was also assessed with three samples of 10 fruit per tree (October 5, 13, and 19, 2009). Internal ethylene 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, we can compare the time of ripening (Table 2, Figure 4). Overall, there was no significant rootstock effect on the time of ripening, but crop load affected it, and the relationship changed with

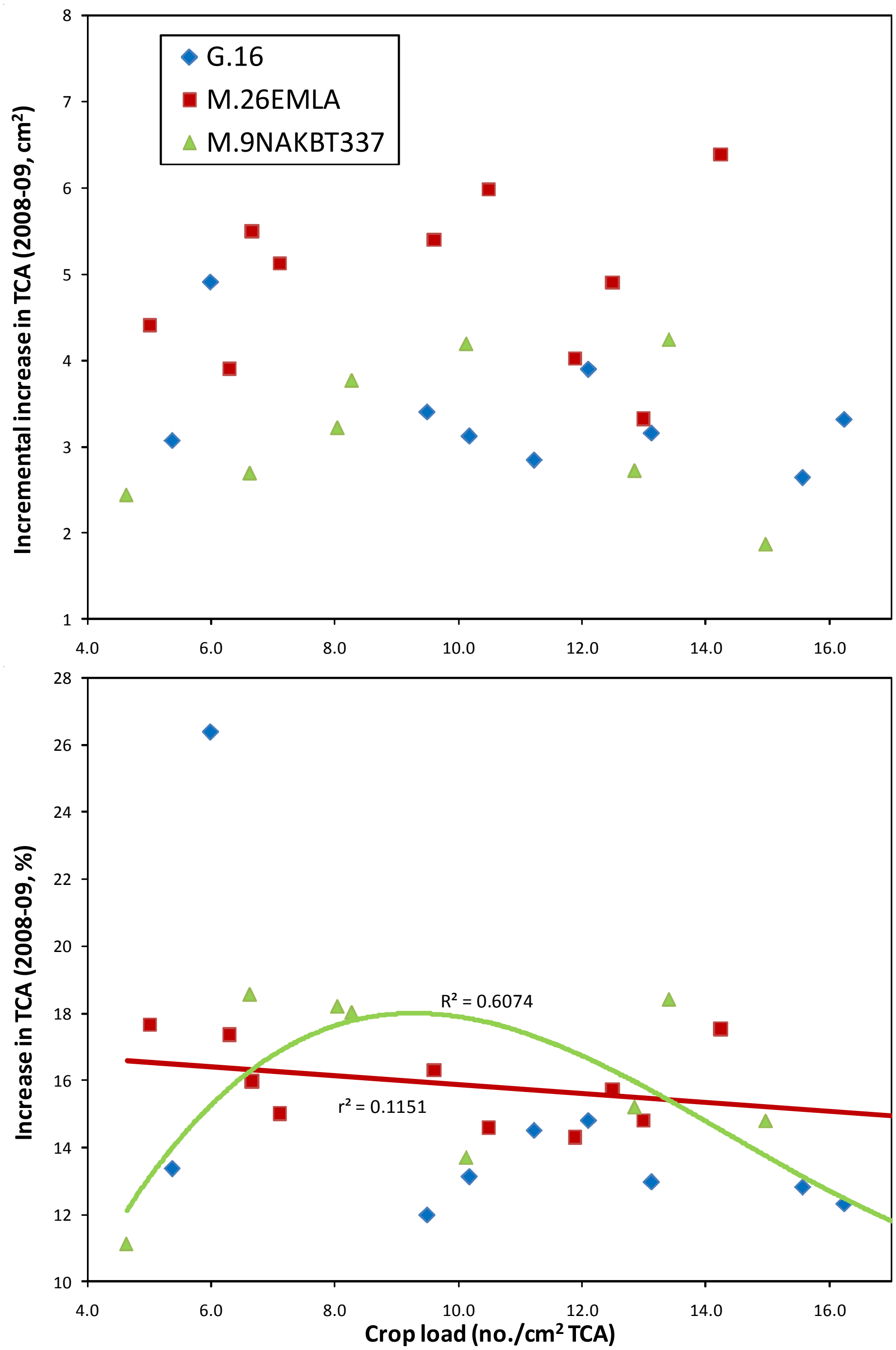

Figure 2. Effects of crop load on trunk growth of Gibson Golden Delicious trees on G.16, M.26 EMLA, or M.9 NAKBT337 in the Massachusetts planting of the 2003 NC-140 Apple Rootstock Physiology Trial.

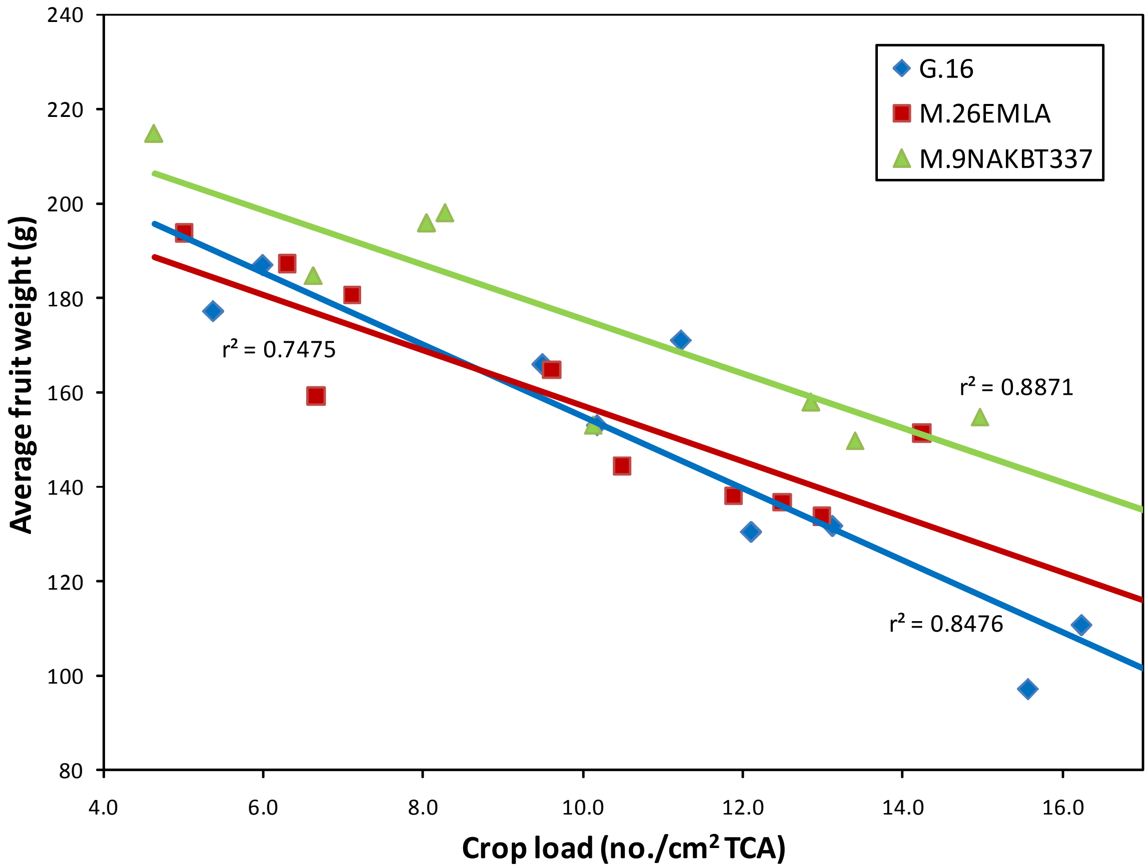

Figure 3. Effects of crop load on size of fruit from Gibson Golden Delicious trees on G.16, M.26 EMLA, or M.9 NAKBT337 in the Massachusetts planting of the 2003 NC-140 Apple Rootstock Physiology Trial.

Table 2. 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 within columns not followed by a common letter are significantly different at odds of 19 to 1 (Tukey's HSD, $P = 0.05$).

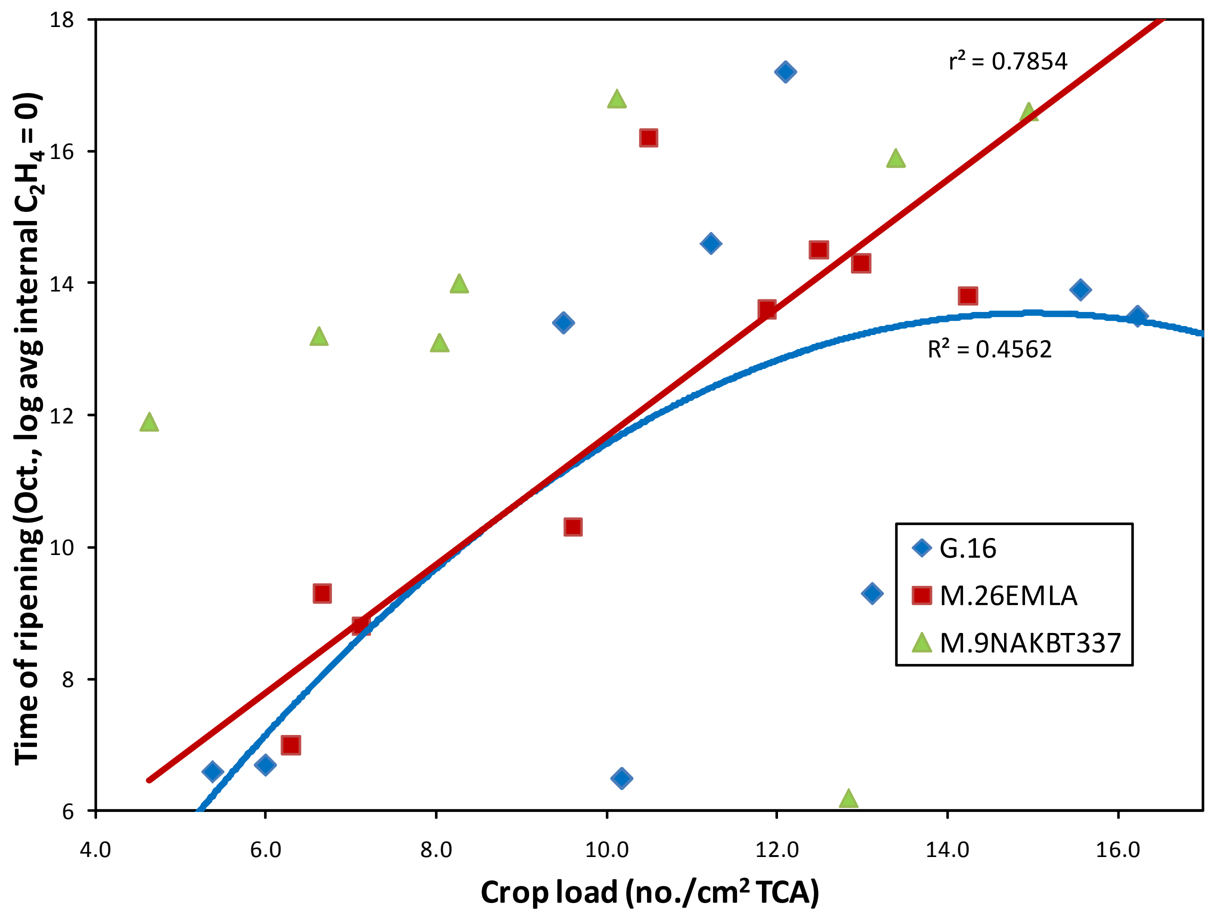

Figure 4. Effects of crop load on the time of ripening of fruit from Gibson Golden Delicious trees on G.16, M.26 EMLA, or M.9 NAKBT337 in the Massachusetts planting of the 2003 NC-140 Apple Rootstock Physiology Trial.

rootstock (Figure 4). 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 2, Figure 5). 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 effects of load varied with rootstock (Table 2, Figure 6). 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 6).

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, starch index responded oppositely to what would be expected with regards to ripening. Specifically, as crop load increased, soluble solids concentration declined, as one would expect, but starch index value increased, even though ripening was delayed (Table 2, Figures 7 and 8). 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.

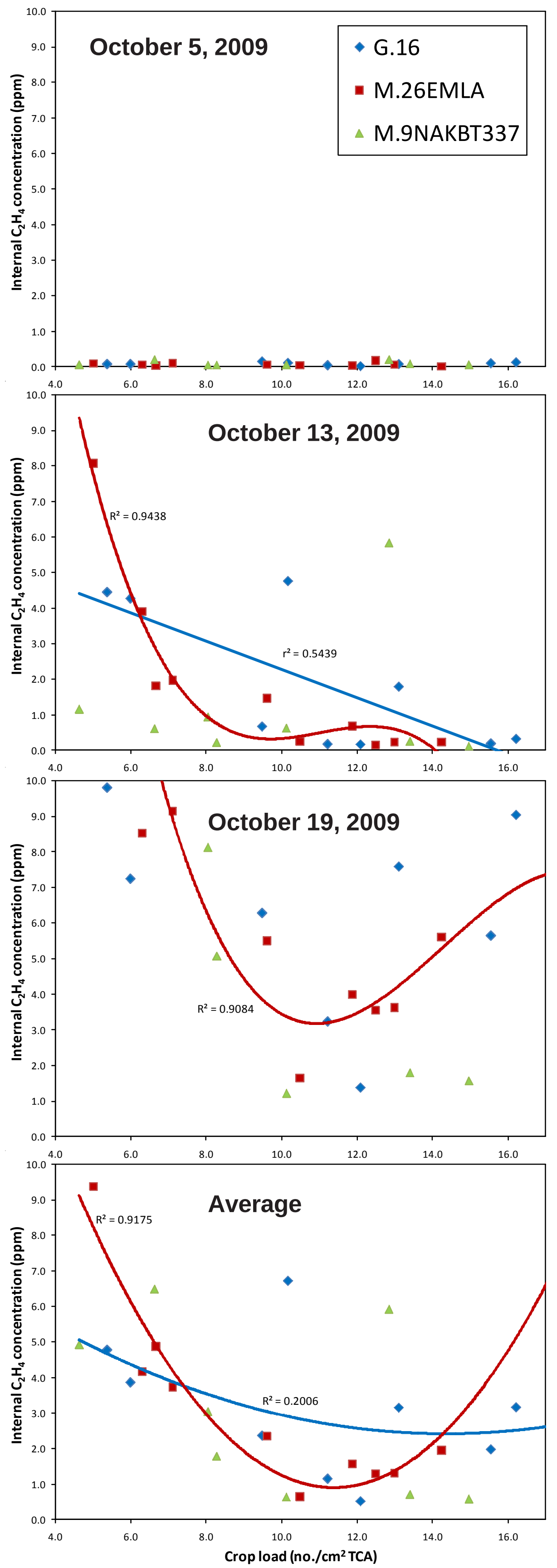

Figure 5. Effects of crop load on internal ethylene concentration of Gibson Golden Delicious fruit.

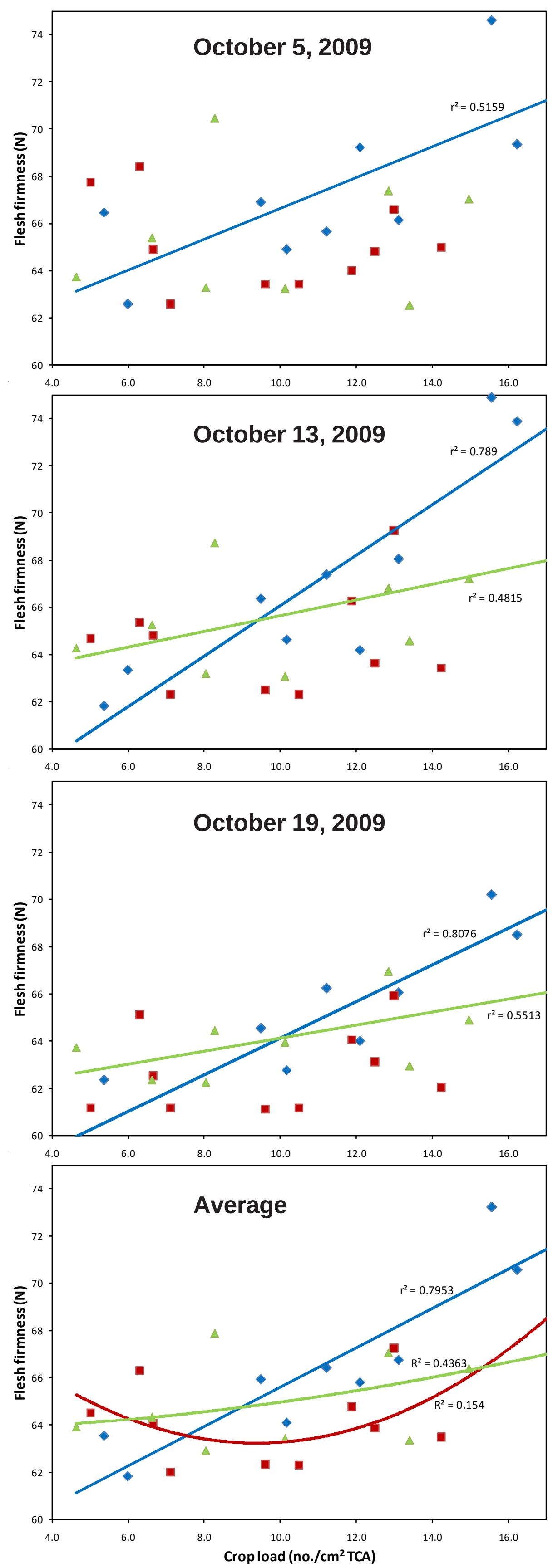

Figure 6. Effects of crop load on flesh firmness of Gibson Golden Delicious fruit.

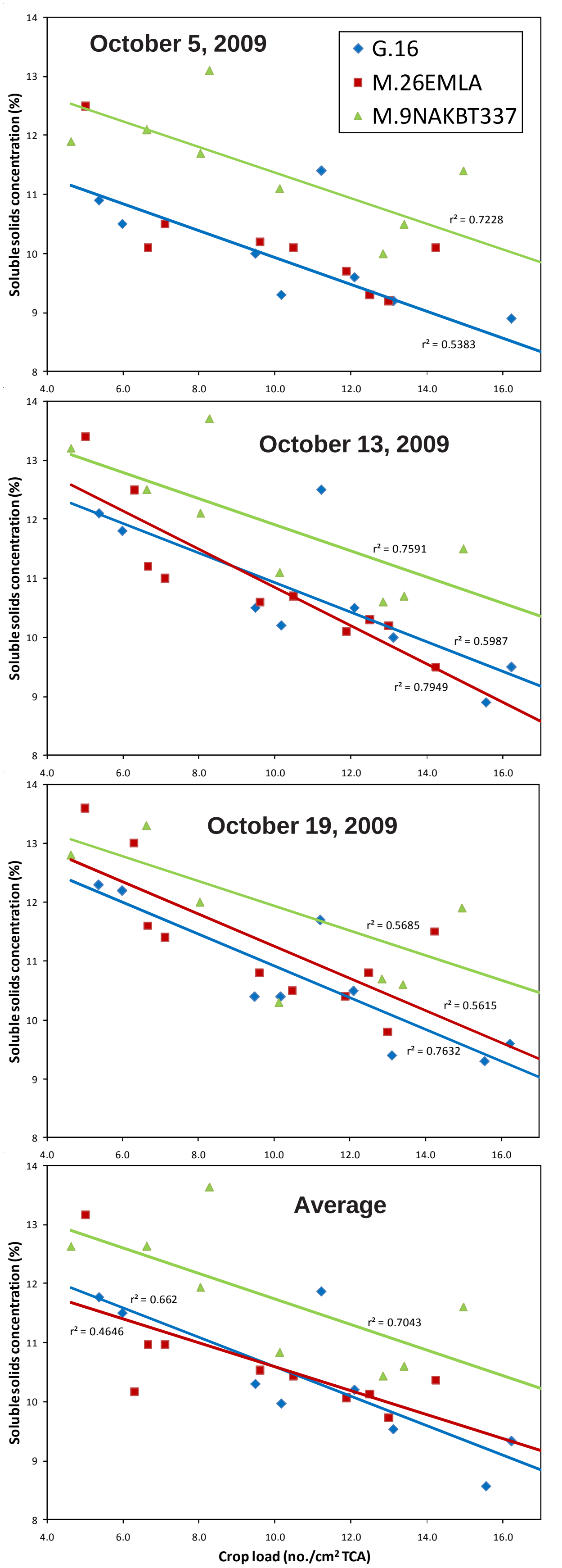

Figure 7. Effects of crop load on soluble solids concentration of Gibson Golden Delicious fruit.

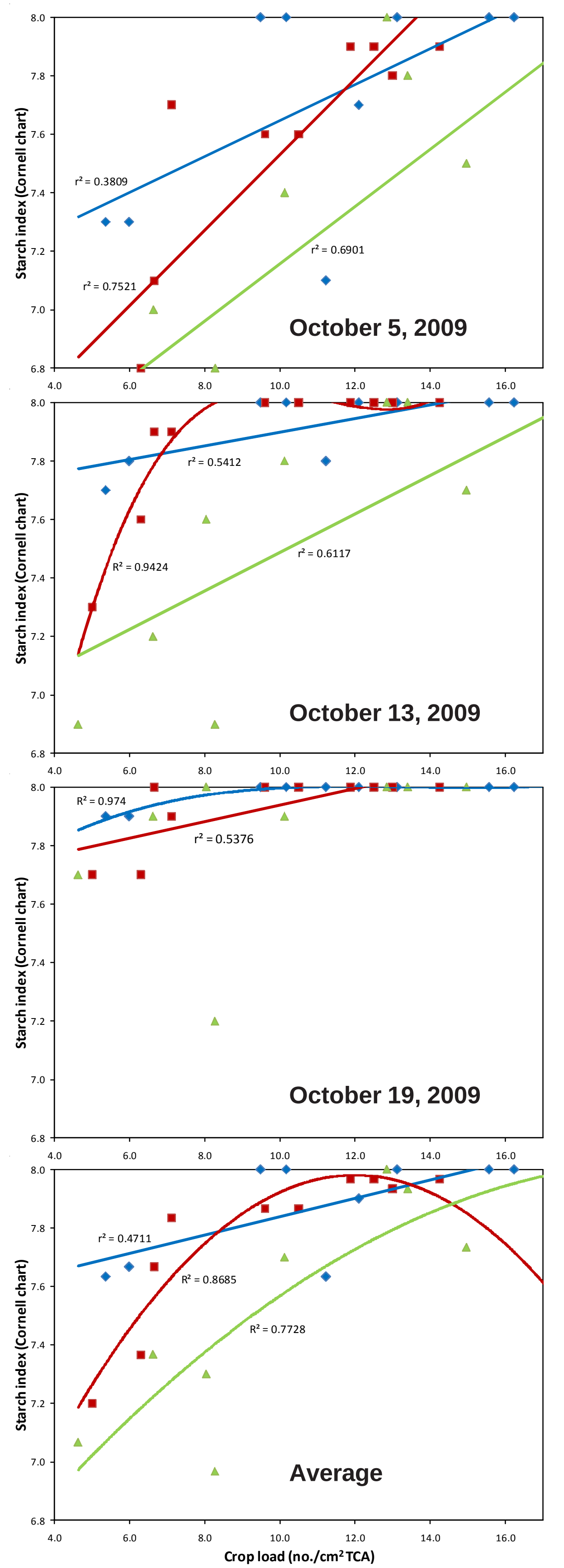

Figure 8. Effects of crop load on starch index value (Cornell chart) of Gibson Golden Delicious fruit.