ANNUAL REPORT TO NC-140
2003 APPLE PHYSIOLOGY TRIAL FOR THE 2009 SEASON

November 2010
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Background

The Apple Physiology Trial was established in spring of 2003 with 14 cooperators and 10 cooperators remain in the trial. Each cooperator received 12 'Golden Delicious' trees on each of three dwarf rootstocks and trees were planted in a completely randomized design at each location.

The table below shows the data sets I have received to date (x indicates that I received data). Years that are shaded indicate that the range in crop density was 2 to 10 and was adequate for analysis of covariance.

Year	BC	CHIH	IA	KY	MA	ME	NJ	NY	ONT	PA	UT	WI
2003	X	X	X	X	X	X	X	X	X	X	X	X
2004	X	X	X	X	X	X	X	X	X	X	X	X
2005	X	X	X	X	X	X	X	X	X	X	X	X
2006	X	X	X	X	X	X	X	X	X	X	X	X
2007	X	X	X	X	X	X	X	X	X	X	X	X
2008	X	X	X	X	X	X	X	X	X	X	X	X
2009	X	X	X	X	X	X	X	X	X	X	X	X

Crop load management and data to be collected in 2011

The 2011 season will be the ninth year of this study. The original plan was to adjust the crop loads in 2006 and again in 2008, and we would collect data on return bloom in 2007 and 2009. For various reasons, such as inadequate tree vigor, hail, frost, and poor fruit set, some cooperators could not adjust crop load in 2006 and/or in 2008. Through the 2009 season, four cooperators (IA, KY, NJ, and ONT) had inadequate fruit set to adequately adjust crop load more than one season.

I suggest that 2011 should be the final year for data collection for this trial. For cooperators who adjusted crop density in 2010, please use the following spread sheet for reporting data. Cooperators who did not adjust crop density in 2010 need not report data.

Below is a sample spread sheet for reporting data for 2010.

STATE __________. Data for the 2003 apple Physiology trial for the 2010 season.

Date of hand thinning: _______________.

Were trees irrigated? ____________.

If there was no irrigation, in your opinion were the trees water stressed enough to adversely affect fruit size? ___________.

Year	site	Tree	rootstock	Status	TCA fall 2010	Avg. fruit wt. (g)	Yield (kg/tree)	Flower density 2010
2010	IA	1	G16	1	32.4	150	14.6	15.1
2010	IA	2	G16	1	38.3	144	12.4	18.9
2010	IA	6	M26	2	.	.	.	.
2010	IA	6	G16	1	25.8	128	16.1	21.1
2010	IA	2	T337	0	.	.	.	.
2010	IA	3	T337	1	29.0	210	9.8	13.3
2010	IA	8	G16	1	31.9	187	11.3	15.9

Below is a sample spread sheet for reporting data collected during the 2010 season

Data Collection and Transmission for data collected in 2010.

1. Send data as an email attachment by March 1, 2011.
2. Avoid the latest versions of spreadsheets
3. **Please proof data sets before sending them to me.**
    - **a.** Make sure you have the appropriate number of trees for each rootstock
    - **b.** Report data in the requested units
    - **c.** Make sure values seem realistic
    - **d.** Make sure rootstock codes are correct and in the correct column
    - **e.** When values are calculated using the spreadsheet, save data as values rather than leaving them as formulas
    - **f.** Make sure variables are entered in the requested columns
4. Report “tree status” as 0=dead, 1=living, or 2=missing. Missing trees are those that are dead or severely injured by mechanical injury, wildlife, or herbicides. If a 2 is recorded for status, then all other columns for that tree should have dots for missing data.
5. When a tree dies, continue to report status for that tree. Do not eliminate the tree from the data set and enter dots for all response variables except “status”.
6. Include dots or periods in all places where data are missing, but enter a zero where zero is the appropriate value.

7. Please enter the entire data set on one sheet. Avoid putting data for different blocks or rootstocks on different sheets within an Excel notebook. I have to consolidate the data set for analysis.

Use the following rootstock codes. Please do not place periods or spaces between letters and numbers in the codes:

Code to report	Rootstock name
M26	Malling 26 EMLA
T337	Malling 9 NAKBT-337
G16	G.16

Below is an example of a spreadsheet for entering data for the 2009 growing season. Please enter response variables in the appropriate columns so I do not have to move columns around.

Cooperators who adjusted crop density in 2010 should report bloom data for 2011 using the following form. Please submit return bloom data by July 1, 2011.

Year	Site	Tree	Root stock code	Status	Flower density 2011
2009	IA	1	G16	1	15.1
2009	IA	2	G16	1	18.8
2009	IA	6	M26	1	9.2
2009	IA	6	G16	2	.
2009	IA	2	T337	1	20.1
2009	IA	3	T337	0	.
2009	IA	8	G16	1	13.8
2009	IA	5	T337	1	16.2

Additional data requested.

The group also discussed the possibility of trying to develop a model for fruit size involving climatic conditions. I requested data, but I received climate data from only 4 cooperators. I will need data from more cooperators to build a model involving climate data. I need the following daily data from full bloom until 60 days after full bloom: daily maximum and minimum temperature (degrees C), daily precipitation (mm), daily light data (kW per m^2 per day if available, but I will try to convert other units of solar radiation), and dates for full bloom, harvest, and fruit thinning. Below is a sample of the spread sheet I would like. **I would like these types of data for 2006, 2007, 2008, 2009, and 2010.**

Location ____Iowa_______

Year ___2009____

Date of full Bloom ____May 3, 2009_______

Date of hand thinning ____May 28, 2009__________

Date of harvest ___October 13, 2009_______________

Year	**Site**	**Days after bloom**	**Max temp (°C)**	**Min temp (°C)**	**Precip (mm)**	**Light (Kw/m^2/day)**
2009	IA	0	22	8	0	8.2
2009	IA	1	19	7	0	8.0
2009	IA	2	15	8	0	3.2
2009	IA	3	23	10	0	7.6
2009	IA	4	24	12	0	9.0
2009	IA	5	28	12	0	8.8
2009	IA	6	19	6	5	1.5
2009	IA	7	19	4	10	1.8
2009	IA	8	17	5	15	1.4
2009	IA	9	12	4	0	3.3
2009	IA	10	13	6	0	4.7
2009	IA	11	15	6	0	5.3
2009	IA	12	14	10	26	7.7
2009	IA	13	22	15	0	8.1
2009	IA	14	24	17	0	8.3
2009	IA	…	…	…	…	…
2009	IA	59	25	16	0	8.1
2009	IA	60	26	17	0	8.2

Results for the seasons 2006 - 2009

Data for all locations where crop density was adjusted for at least two years were combined into one data set and an analysis of covariance was performed. Since the four-way interaction of location*year*stock*CD was significant, data for each location were analyzed separately, where CD was included as a covariate and year and rootstock were included as indicator (class) variables and a summary of the analysis is presented in Table 1. Year was significant for five of the nine locations with adequate CDs for at least two years, rootstock was significant for eight of the 12 locations and the rootstock * year interaction term was significant for three of the nine locations (Table 1). The covariate CD was significant for all locations and it interacted with year for three locations and with rootstock for only MA. The three-way interaction of CD*year*stock was not significant at any location. The non-significant CD*Stock interaction would typically lead one to fit equal slopes models for years or root stocks. However, since the primary reason for conducting this trial was to evaluate the interaction of CD and rootstock, an *a priori* decision was made to use estimate statements to make all pair-wise comparisons of rootstock within each year for each location with a comparison-wise error rate of 0.05 and an approximate family-wise error rate of 0.142 for the three comparisons. In some cases, the difference between two slopes appeared large, but the slopes did not differ significantly because standard errors of the estimate were large; at most location the standard errors were less than 2.0, but at KY, UT and WI the standard errors exceeded 7.0.

Slopes and intercepts, obtained with the solution option in the model statement are presented for each combination of year and location in Table 2. For BC the slopes for the three rootstocks were similar in 2006, but in 2009 G.16 had the least negative slope (Table 2). An equal slopes model was fit to test the hypothesis that slopes, pooled across rootstocks, were equal for the two years and the slope for 2008 (-11.92) was significantly more negative than the slope for 2006 (-7.64). For IA slopes for the three rootstocks did not differ. For KY the slopes were homogenous both years, but the year by rootstock interaction was significant because the slope for M.26 was most negative in 2006 and least negative in 2008. For MA, CD interacted with both year and stock. The slopes were homogeneous in 2007, but in 2009 M9.T337 had the least negative slope. Of the three estimate statements that were used to compare years within rootstocks, only slopes for M.26 were different, where the slope for 2009 was more negative than for 2007. For ME, CD was significant but none of the interaction terms were significant, so the six slopes were homogeneous. For Mexico M.9T337 had the most negative slope and G.16 had the least negative slope in 2006, but in 2009 the three slopes were homogeneous. Since none of the interaction terms were significant, a common slope of -7.87 was estimated for all six combinations of rootstock and year. For NJ, the CD*stock interaction term was significant and M.9T337 had a less negative slope than G.16 or M.26. For NY there was adequate CD to include all four years in the analysis and the CD*year interaction term was significant although slopes were homogenous within each year. When common slopes were estimated for each year, 2006 was significantly less negative (-1.74) than slopes for the other years (-8.23, -6.83, and -7.90 for 2007, 2008, and 2009, respectively). Estimate statements used to compare slopes of the three rootstocks pooled over the four years indicated that the slope for G.16 was more negative (-8.42) than slopes for M.26 (-6.63) and M9.T337 (-6.21). For Ontario, the CD*rootstock interaction term was significant and the slope for G.16 was less negative than the slope for M.9T337. Pennsylvania had adequate CD in three years but the interaction terms were not significant, and slopes within years were homogenous. When slopes were estimated for years pooled over rootstocks the slope for 2008 was more negative than for 2006. Pair-wise comparisons for years within each rootstock indicated that for M.26, but not for other rootstocks, the slope in 2006 was less negative than in 2008. For UT, none of the interaction terms were significant and the slope for 2006 pooled over all rootstocks was less negative than the slope for 2008. Wisconsin had adequate CD in three years and the CD*year interaction term was significant at P=0.57. In 2008 M.9T337 had a more negative slope than the other rootstocks, and slopes for the three rootstocks did not differ in 2007 and 2009..

In an attempt to summarize the relationship between CD and rootstock for all years, the slopes were ranked from 1 to 3, where 3 was most negative, within each location and year. The mean rankings were 1.96, 2.30 and 1.74 for G.16, M.26 and M.9T337, respectively and they did not differ at the 5% level (P=0.060). Therefore, there is little evidence that the relationship between FW and CD is consistently influenced by rootstock. However, the intercepts appeared different. Interpretation of intercepts is not possible because this would be the FW at a CD of zero, and it is biologically not possible to record FW when there are no fruit. In an attempt to compare intercepts, the intercepts within each location and year were ranked from 1 to 3, where 1 was the lowest value. The average intercept ranking G.16 (1.56) was significantly lower than for M.26 (2.08) and M9.T337 (2.36), supporting the observation that at a given CD, trees on G.16 produced smaller fruit than trees on the other rootstocks.

To further evaluate the influence of rootstock on FW, SAS' Lsmeans statement was used to compute adjusted means at three levels of CD for each rootstock at each combination of location and year and adjusted means within location and year were compared with pdiff (similar to LSD) at the of 5% level of significance (pair-wise comparison rate).

For BC, trees on G.16 consistently produced the smallest fruit and trees on M.9T337 produced the largest fruit in 2006 and in 2008 regardless of CD (Table 3). For IA trees on M.9T337 produced the largest fruit but differences were significant only at CDs ≤ 6. For KY, FW was not influenced by rootstock in 2008, but in 2006 trees on M.26 produced larger fruit than G.16 at CD=2, whereas M.9T337 produced the largest fruit at CDs ≤ 6. For MA, trees on M9.T337 consistently produced the largest fruit at all CDs in 2007, but in 2009 the difference was significant only at CD=10. For ME, FW was highest for trees on M.9T337 in 2007, and although the trend was similar in 2009 the differences were not significant at the 5% level. In general FW was quite low for Mexico and variation was higher than at most locations. Results in Mexico were inconsistent for the two seasons. In 2006, FW was highest for trees on M.9T337 for only CD=2 and in 2009 trees on M.9T337 produced the smallest fruit, but differences were significant only at the intermediate CD. NJ had adequate CD in only 2006 and there was a significant interaction between CD and rootstock because the slope was positive for M.9T337; trees on M.9T337 had the lowest FW at CD=2 and the highest FW at CD=10. For NY trees on G.16 tended to produce the smallest fruit all four years, but differences were significant at the 5% level for only 2008 and 2009, especially at the higher CDs. For Ontario, FW was highest for M.9T337 at only the lowest CD. For PA, trees on G.16 consistently produced the smallest fruit, but differences were significant only in 2008. For UT, rootstock did not significantly influence FW in either year. For WI, trees on G.16 usually had smaller fruit than trees on M.9T337, but in 2008 and 2009 trees on M.26 produced the smallest fruit. Differences were not significant in only 2008.

Summary

The primary objective of this study was to determine if rootstocks influence fruit size over a range of crop densities at different locations. This study produced 25 combinations of locations and years with CDs ranging from about 2 to 10 fruit·cm^{-2} TCA. There was quite a bit of variation in average FW. The largest fruit were harvested in BC and NJ and the smallest fruit were harvested in Mexico. In general FW declined with increasing CD, but the effect of rootstock on this relationship was not very consistent, indicating that the influence of CD on FW is not strongly affected by rootstock. This conclusion is supported by the fact that the CD*rootstock interaction was significant at only MA. Normally the lack of CD*rootstock interaction would lead one to perform a normal analysis of covariance where slopes are parallel and FW means are compared at the mean level of the covariate, CD. However, since the location*rootstock*yr*CD interaction was significant and the yr*CD interaction was significant at five locations, means for FW were estimated at three levels of CD for each year, as would be done if the CD*yr*rootstock interaction was significant. Because the CD*rootstock interaction was usually modest, results for the multiple comparisons were usually similar at each level of CD. Adjusted values for FW were most often highest for trees on M.9T337 and most often lowest for trees on G.16. Results from this study provide strong evidence that FW can be influenced by rootstock regardless of CD and it generally supports results from previous NC-140 trials where CD was adjusted to commercially acceptable levels.

Table 1. P-values from the analysis of covariance model containing significant (P = 0.05) terms.

Source	BC	IA[z]	KY	MA	ME	MEX	NJ[z]	NY	ONT[z]	PARS	UT	WI
Yr (Y)	0.001	- - -	0.038	0.28	0.244	0.007	- - -	0.001	- - -	0.785	0.001	0.055
Stock (S)	0.001	0.001	0.011	0.72	0.001	0.118	0.001	0.001	0.001	0.001	0.743	0.071
Y*S	0.104	- - -	0.001	0.001	- - -	0.082	- - -	0.124	- - -	0.079	0.707	0.057
CD	0.001	0.001	- - -	- - -	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
CD*Y	0.001	- - -	- - -	0.020	- - -	- - -	- - -	0.011	- - -	- - -.	- - -.	- - -
CD*S	- - -	- - -	- - -	0.030	- - -	- - -	0.007	- - -	0.002	- - -	- - -	- - -

[z] Locations where crop density was adjusted only one so the model included only rootstock, Cd and CD*rootstock.

Table 2. Slopes and intercepts for three rootstocks and four years at12 locations. Values were generated with the solution option in the model statement of SAS' Mixed Procedure.[z]

	2006		2007		2008		2009	
Stock	Int.	Slope	Int.	slope	Int.	Slope	Int.	Slope
British Columbia								
G.16	271.05	-10.11a	- - -	- - -	268.62	-11.02a	- - -	- - -
M.26	254.76	-7.18a	- - -	- - -	299.03	-12.39b	- - -	- - -
M.9T337	259.09	-6.48a	- - -	- - -	301.81	-11.73b	- - -	- - -
Iowa								
G.16	178.81	-7.43a	- - -	- - -	- - -	- - -	- - -	- - -
M.26	193.85	-9.60a	- - -	- - -	- - -	- - -	- - -	- - -
M.9T337	191.90	-7.50a	- - -	- - -	- - -	- - -	- - -	- - -
Kentucky								
G.16	160.41	-2.56a	- - -	- - -	185.21	-6.70a	- - -	- - -
M.26	234.22	-12.28a	- - -	- - -	152.03	-2.94a	- - -	- - -
M.9T337	200.04	-3.42a	- - -	- - -	197.38	-5.89a	- - -	- - -
Massachusetts								
G.16	- - -	- - -	241.57	-8.40a	- - -	- - -	247.89	-10.35b
M.26	- - -	- - -	232.50	-7.12a	- - -	- - -	258.65	-10.52b
M.9T337	- - -	- - -	252.37	-7.11a	- - -	- - -	248.02	-7.77a

Maine								
G.16	- - -	- - -	250.67	-12.06a	- - -	- - -	254.72	-11.06a
M.26	- - -	- - -	232.41	-8.69a	- - -	- - -	252.82	-11.33a
M.9T337	- - -	- - -	261.53	-10.17a	- - -	- - -	256.45	-10.07a
Mexico								
G.16	152.72	-5.42a	- - -	- - -	- - -	- - -	154.08	-6.33a
M.26	166.94	-6.92a	- - -	- - -	- - -	- - -	192.00	-13.42a
M.9T337	198.15	-11.32a	- - -	- - -	- - -	- - -	140.10	-9.36a
New Jersey								
G.16	251.29	-5.36a	- - -	- - -	- - -	- - -	- - -	- - -
M.26	279.77	-6.42a	- - -	- - -	- - -	- - -	- - -	- - -
M.9T337	210.51	+2.30b	- - -	- - -	- - -	- - -	- - -	- - -
New York								
G.16	176.41	-3.10a	227.95	-12.45a	204.01	-4.71a	212.10	-8.98a
M.26	163.19	-0.62a	217.86	-8.15a	261.33	-8.99a	227.61	-5.24a
M.9T337	176.83	-0.92a	224.50	-9.63a	230.19	-2.62a	239.29	-8.61a
Ontario								
G.16	160.03	-0.09a	- - -	- - -	- - -	- - -	- - -	- - -
M.26	179.72	-2.81ab	- - -	- - -	- - -	- - -	- - -	- - -
M.9T337	198.32	-5.17b	- - -	- - -	- - -	- - -	- - -	- - -
Pennsylvania								
G.16	195.86	-5.20a	187.58	-6.79a	185.59	-7.19a	- - -	- - -
M.26	212.86	-5.37a	205.96	-8.99a	241.57	-11.69a	- - -	- - -
M.9T337	203.10	-4.06a	188.92	-3.37a	197.57	-5.72a	- - -	- - -
Utah								
G.16	205.48	-8.46a	- - -	- - -	202.10	-8.90a	- - -	- - -
M.26	221.71	-1.97a	- - -	- - -	193.76	-8.72a	- - -	- - -
M.9T337	239.21	-6.23a	- - -	- - -	184.64	-6.09a	- - -	- - -
Wisconsin								
G.16	- - -	- - -	201.83	-4.43a	219.99	-7.80a	187.08	-5.47a
M.26	- - -	- - -	221.65	-5.69a	211.14	-10.72a	199.77	-9.10a
M.9T337	- - -	- - -	219.60	-4.83a	268.11	-16.75b	204.91	-7.34a

[z] Slopes within year and location followed by common letters do not differ at the 5% level of significance by PDIFF.

Table 3. Average FW as influenced by three rootstocks in four years. Values are LSmeans computed at three levels of crop density (2, 6 and 10 fruit/cm2^{2}). [z]

	2006			2007			2008			2009		
stock	2	6	10	2	6	10	2	6	10	2	6	10
British Columbia												
G.16	238a	207a	176a	- - -	- - -	- - -	249a	202a	156a	- - -	- - -	- - -
M.26	243ab	212ab	182ab	- - -	- - -	- - -	272b	225b	179b	- - -	- - -	- - -
M9.T337	254b	223b	192b	- - -	- - -	- - -	278b	231b	185b	- - -	- - -	- - -
Iowa												
G.16	164a	134a	105ab	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
M.26	175a	136a	98a	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
M9.T337	177a	147b	117b	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Kentucky												
G.16	155a	145a	135a	- - -	- - -	- - -	172a	145a	118a	- - -	- - -	- - -
M.26	210b	160ab	111b	- - -	- - -	- - -	147a	135a	123a	- - -	- - -	- - -
M9.T337	194ab	180b	166a	- - -	- - -	- - -	186a	162a	138a	- - -	- - -	- - -
Massachusetts												
G.16	- - -	- - -	- - -	225ab	191a	158a	- - -	- - -	- - -	227a	186a	144a
M.26	- - -	- - -	- - -	218a	190a	161a	- - -	- - -	- - -	238a	196a	153a
M9.T337	- - -	- - -	- - -	238b	210b	181b	- - -	- - -	- - -	232a	201a	170b
Maine												
G.16	- - -	- - -	- - -	227a	178a	130a	- - -	- - -	- - -	233a	188a	144a
M.26	- - -	- - -	- - -	215a	180a	146ab	- - -	- - -	- - -	230a	185a	140a
M9.T337	- - -	- - -	- - -	241b	201b	160b	- - -	- - -	- - -	236a	196a	156a
Mexico												
G.16	142a	120a	98a	- - -	- - -	- - -	- - -	- - -	- - -	141a	116b	91a
M.26	153a	125a	98a	- - -	- - -	- - -	- - -	- - -	- - -	165a	111ab	58a
M9.T337	176b	130a	85a	- - -	- - -	- - -	- - -	- - -	- - -	121a	84a	47a
New Jersey												
G.16	241ab	219a	198a	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
M.26	267b	241b	216b	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
M9.T337	215a	224ab	234ab	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
New York												
G.16	170a	158a	145a	204a	153a	103a	195a	176a	157a	194a	158a	122a
M.26	164a	167a	169a	202a	169a	136a	243b	207b	171a	217a	196b	175b
M9.T337	175a	171a	168a	205a	167a	128a	225ab	215b	204b	222a	188b	153b
Ontario												
G.16	160a	159a	159a	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
M.26	174ab	163a	152a	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
M9.T337	189b	167a	147a	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Pennsylvania												
G.16	185a	164a	143a	174a	147a	120a	171a	142a	114a	- - -	- - -	- - -
M.26	202a	181b	160a	188a	152a	116a	218c	171b	125ab	- - -	- - -	- - -
M9.T337	195a	179b	163a	182a	169b	155a	186b	163b	140b	- - -	- - -	- - -

Utah												
G.16	234a	200a	166a	- - -	- - -	- - -	186a	153a	120a	- - -	- - -	- - -
M.26	218a	210a	202a	- - -	- - -	- - -	176a	141a	107a	- - -	- - -	- - -
M9.T337	227a	202a	177a	- - -	- - -	- - -	172a	148a	124a	- - -	- - -	- - -
Wisconsin												
G.16	- - -	- - -	- - -	204a	171a	139a	205b	173b	140b	186a	153a	121a
M.26	- - -	- - -	- - -	214ab	182ab	149ab	186a	153a	121a	180a	148a	115a
M9.T337	- - -	- - -	- - -	226b	193b	161b	212b	179b	146b	193a	161a	128a

[z] Data were analyzed with analysis of covariance by location, where crop density was included as a covariate in the model of SAS' Mixed procedure. Lsmeans within location and year followed by the same letter do not differ at the 5% level of significance by PDIFF.

Annual Trunk Growth – data are discussed only for BC to demonstrate how we can evaluate these data.

The influence of rootstock, location and CD on annual trunk growth was evaluated by calculating the difference in TCA from one year to the next for each tree. Each location was analyzed separately because sites were not in sink in terms of cropping. ANCOVA was performed for each year per location, where CD was used as the covariate and rootstock was the indicator variable. Slopes and intercepts obtained with the solution option in the model statement are presented in Table 4 and the slopes were compared with estimate statements. LSmeans were estimated for each year and rootstock and were compared with PDIFF.

British Columbia: For all years, the CD*stock interaction was not significant, so rootstock did not influence the relationship between TCA increase and CD. Regression models were produced for each rootstock each year and contrast statements were used to compare intercepts and estimate statements were used to compare slopes. Although crop load was adequate for crop load adjustment in only 2006 and 2008, TCA increase was negatively related to CD every year. TCA increase was significantly affected by rootstock in 2007, 2008 and 2009. Due to lack of a significant rootstock*CD interaction in 2006, models were fit with a common slope of -0.288, indicating that as CD increased by one fruit per cm^2 of TCA, trunk enlargement decreased by 0.29 cm^2. Intercepts estimated with the common slopes model were 5.35, 6.32, and 6.19 for G.16, M.26 and M.9T337, respectively. In 2007 rootstock and CD influenced trunk enragement; trunk enlargement was lowest for trees on G.16 and highest for trees on M.26 and slopes were not different. In 2008 and 2009 trunk enlargement was highest for trees on M.26 and lowest for trees on G.16, but slopes were most negative for M.26 indicating that CD influenced trunk enlargement more for trees on M.26 than for the other rootstocks. Even after adjusting for CD, trees on M.26 trunks grew more than trunks for trees on the other rootstocks.

Means for TCA are presented in Table 5, but data were not analyzed statistically. These values are presented to for TCA to show the variation in TCA due to location and rootstock.

Table 4. Annual TCA enlargement of ‘Golden Delicious’ trees for four years as influenced by rootstock and crop density in British Columbia. Analysis of covariance was used to generate intercepts and slopes, LSmeans and P-values. The top section of the table contains slopes and intercepts for each rootstock using CD as the covariate; the middle section contains LSmeans for annual TCA increase adjusted for CD, and the lower section contains P-values for the three terms in the linear model.

	2006		2007		2008		2009	
Stock	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	slope
G.16	4.46	-0.168	8.4ab	-1.93	5.49a[z]	-0.43b	4.76b	-0.07a
M.26	6.60	-0.325	10.3a	-1.80	7.74a	-0.54b	11.87a	-1.63b
M.9T337	6.64	-0.343	7.4b	-0.85	2.93b	+0.12a	8.46ab	-1.25ab
Least Squares means for TCA enlargement adjusted for the mean value of CD								
G.16	3.24		5.77b		3.29b		4.60b	
M.26	4.21		7.69a		4.84a		7.96a	
M.9T337	3.91		6.25ab		3.58ab		5.47b	
Significance from ANCOVA								
Stock	0.226		0.001		0.001		0.001	
CD	0.001		0.001		0.013		0.002	
CD*stock	0.488		0.237		0.051		0.094	

[z] Values within columns and table sections followed by common letters do not differ at the 5% level of significance by PDIFF.

Table 5. Trunk cross-sectional area (cm^2) as affected by three rootstocks at 13 locations for seven years.[z]

stock	2003	2004	2005	2006	2007	2008	2009
Arkansas							
G.16	- - -	4.7	11.4	17.9	31.5	- - -	- - -
M.26	- - -	4.3	12.3	16.8	31.0	- - -	- - -
M9.T337	- - -	4.6	10.2	17.4	28.8	- - -	- - -
British Columbia							
G.16	2.9	8.2	14.1	17.3	23.1	26.3	31.0
M.26	2.5	8.1	14.6	18.8	27.1	32.0	40.3
M9.T337	2.8	7.6	13.8	17.7	23.4	27.0	31.0
Iowa							
G.16	2.5	5.6	10.8	113.6	20.9	26.9	34.4
M.26	2.0	4.8	10.4	15.5	27.9	36.8	50.7
M9.T337	1.6	4.0	7.9	111.2	19.4	26.2	36.8
Kentucky							
G.16	2.4	10.0	18.4	24.9	37.9	44.6	61.1
M.26	1.8	9.0	21.0	31.2	47.6	56.9	80.3
M9.T337	1.9	7.8	18.9	28.8	45.6	55.6	77.8
Massachusetts							
G.16	1.4	2.4	6.9	12.4	15.9	23.5	26.9
M.26	1.3	5.6	8.0	14.7	19.8	30.8	35.7
M9.T337	1.3	2.0	5.0	8.6	11.3	18.7	21.5
Maine							
G.16	2.0	4.1	9.3	16.6	22.6	30.3	37.3
M.26	1.8	3.6	8.7	16.7	21.3	32.7	46.7
M9.T337	1.9	5.9	6.6	11.5	17.1	24.1	29.0
Mexico							
G.16	8.1	11.6	14.4	18.0	26.1	33.4	38.5
M.26	7.1	11.2	14.2	17.9	27.5	35.2	38.8
M9.T337	7.6	10.2	12.6	14.3	20.0	20.6	22.5
New Jersey							
G.16	3.0	8.1	12.9	15.5	24.4	33.5	- - -
M.26	2.9	8.4	16.0	17.4	32.0	47.0	- - -
M9.T337	2.7	6.2	10.3	14.1	20.7	30.2	- - -
New York							
G.16	3.0	5.4	10.0	16.6	20.9	26.0	34.7
M.26	1.7	4.4	9.2	15.7	20.9	28.4	38.1
M9.T337	1.9	4.2	8.0	14.0	18.3	24.8	35.3
Ontario							
G.16	3.0	4.7	15.8	16.6	19.4	19.4	22.2
M.26	3.1	4.9	15.1	16.2	20.7	20.6	24.2
M9.T337	2.3	5.4	11.2	14.3	17.0	17.1	20.0

Pennsylvania							
G.16	2.5	8.0	12.5	18.5	23.3	27.8	34.7
M.26	2.1	6.9	13.2	21.0	30.8	39.7	54.6
M9.T337	2.7	7.4	12.4	19.2	27.1	34.5	45.8
Utah							
G.16	4.1	11.9	17.1	21.9	27.4	32.4	37.2
M.26	3.0	9.8	16.4	25.4	32.2	41.4	51.3
M9.T337	2.8	8.7	14.5	21.8	28.7	35.1	33.9
Wisconsin							
G.16	2.0	5.7	10.8	20.5	22.1	28.9	38.4
M.26	2.3	6.4	12.0	18.3	32.7	46.5	64.0
M9.T337	2.0	5.7	11.3	19.8	25.9	35.0	46.3

[z] The site*stock interaction was significant in 2003 and 2004 (P=0.001), not in 2005 (P=0.072), or in 2006 (P=0.061), but the interaction was significant in 2007 (P=0.003), and in 2008 & 2009 (P=0.001) .

Return Bloom

Flower density was influenced by rootstock in all three seasons, even season following relatively low CDs (Table 6). CD was highest in 2006 and moderate in 2008 and flower density, but every year flower density was related negatively to CD the previous season. In 2007 Flower Density declined in a quadratic manner as CD increased and flower density was highest for trees on M.26. Flower Density was negatively affected in a linear manner by the previous season's CD in 2008 and 2009 following relatively low CDs. When adjusted for the previous season's CD, trees on G.16 consistently had the lowest flower densities.

Table 6. Flower density of 'Golden Delicious' trees in three years in British Columbia as influenced by rootstock and CD the previous season. Intercepts and regression coefficients were obtained from an ANCOVA, where flower density was the response variable, rootstock was the qualitative treatment variable and the previous season's CD was the covariate.

	2007			2008		2009	
Stock	Intercept	Linear	Quad	Intercept	Slope	Intercept	slope
G.16	4.34	-0.621	0.021	15.15b	-0.567	3.15b	-0.348
M.26	6.15	-1.104	0.053	13.98b	+0.616	6.27a	-0.710
M.9T337	3.41	-0.278	0.006	22.25a	-2.020	7.442a	-0.824
Least Squares means for Flower Density adjusted at the mean value of the previous season's CD							
G.16	1.29b [z]			14.37b		1.31b	
M.26	1.80a			14.84b		2.52ab	
M.9T337	1.61ab			19.45a		3.07a	
Significance from ANCOVA							
Stock	0.001			0.001		0.001	
CD	0.002			0.036		0.001	
CD*stock	0.257			0.326		0.182	
CD^2	0.036			0.623		0.482	

[z] LSmeans, adjusted for the previous season's CD, followed by common letters do not differ at the 5% level of significance by PDIFF.