Journal of the American Pomological Society 61(2):84-96 2007

Performance of Apple Cultivars in the 1999 NE-183 Regional Project Planting. I. Growth and Yield Characteristics

R. Crassweller, R. McNew, D. Greene, S. Miller, J. Cline, A. Azarenko, B. Barritt, L. Berkett, S. Brown, W. Cowgill, E. Fallahi, B. Fallahi, E. Garcia, C. Hampson, T. Lindstrom, I. Merwin, J.D. Obermiller, M. Stasiak, G. Greene II

Abstract

A multi-site experiment to evaluate the performance of 23 apple (*Malus* × *domestica* Borkh.) cultivars was established in 1999. The purpose was to evaluate new and promising cultivars and breeding selections in a range of geographical and climatic areas within North America. All trees were propagated on M.9T337 and minimally pruned to encourage early bearing. 'Pinova' and 'Cripp's Pink' had the most flower clusters in the first year after planting. At the end of the fifth growing season 'Cripp's Pink' trees were among the largest while NY 65707-19 and 'Minnewashta' were the smallest. CQR10T17 and 'Golden Delicious' had the greatest cumulative yield. 'Pinova' had the highest yield efficiency and highest mean number of fruit per year. The largest fruit were produced on NY 75907-49. Three breeding selections NJ 90, NY 65707-19 and NY 75907-49 had pre-harvest fruit drop in excess of 20%. 'Chinook' had the heaviest annual crop load but also had the smallest fruits. 'Minnewashta' and 'Silken' were the earliest blooming cultivars while 'Runkel' bloomed the latest. Across all sites the average days from bloom to harvest was 184 days for 'Cripp's Pink' making it the latest cultivar to mature and probably not suited to be grown in more northern regions of the continent.

It has been estimated that there are in excess of 10,000 named apple cultivars (15); however, only about 15 cultivars are traded on an international basis. Even so, commercial fruit growers are constantly trying to find new cultivars that can command a higher monetary value. Typically when a new high-quality cultivar is released, supply is low and prices will be high. As supply increases then prices respond by dropping. The ideal situation is for fruit growers to be marketing the new cultivar before supply increases and its value declines. The current high cost of establishing an orchard and the risk of planting a cultivar that has a low demand make it vital that information on cultivar performance across a wide range of growing environments is readily available.

The world apple production has rapidly increased in recent years with the People's Republic of China leading the way as the largest producer (5). Much of the rapid rise in global production can be attributed to the discovery and release of new apple cultivars (10). 'Fuji' and 'Gala' are examples of two new cultivars that fueled the expansion of the industry. 'Fuji' is now the world's leading apple cultivar. O'Rourke et al. (10) estimated that total production of all apple cultivars will increase by 7% between 2005 and 2010.

The NE-183 project as outlined (4) was the first organized research project that attempted to standardize the testing of new apple cultivars across a wide geographical region. This paper presents the results of the growth and yield parameters of the 1999 planting from 17 sites in North America.

Materials and Methods

The overall design and objectives for the study have been described previously (4). The experimental design was a randomized complete block at each location, with five replicate trees per cultivar; filler trees and guard trees were provided by individual cooperators as necessary. Tree training was carried out according to commercial practices, with the general goal of a pyramid-shaped

canopy and minimal pruning in the first two years. The date when 90% of the flowers reached full bloom was recorded each year. In the year of planting all fruit that developed were removed. In the second year, blossom clusters were counted with a local option to leave or remove fruit. In subsequent years fruit were thinned to a spacing of 15-20 cm, and singled to one fruit per spur.

Trunk cross-sectional area (TCSA) was calculated from trunk circumference measured at 30 cm above the graft union at the end of each growing season. Tree height and spread were measured in the fall of 2004. Spread was determined by averaging the in-row and cross-row spread of the trees. The height:spread ratio (H:S) was calculated from each individual tree measurements.

The number of flower clusters per tree was counted in 2000 and thereafter bloom was rated each year. A rating scale (0 to 5) was used where 0 = no bloom, 3 = a full crop and 5 = a snowball bloom.

The goal of the cooperators was to harvest fruit when the starch index rating ranged between 4 and 6 based on the Cornell Generic Starch–Iodine Chart (1). At harvest fruit number (NF) and weight of all harvested fruit were determined for each tree. Dropped fruit were counted each year but not weighed. Mean percent dropped fruit (%DF) was determined by dividing the drops by the total number of fruit (dropped fruit + harvested fruit) and multiplying by 100. The cumulative yield (CY) for each cultivar was then determined by computing the sum of all annual yields. Cumulative yield efficiency (CYE) for each cultivar was determined by taking the CY and dividing by the TCSA for the year 2004.

Average fruit weight (FW) was the annual yield of harvested fruit divided by the number of fruit per tree. Biennial bearing index (BI) was determined as described by Pearce and Debusek-Urbank (11) and utilizing the number of fruit each year. Crop load (CL) was calculated by dividing the number of harvested fruit by the yearly TCSA.

Response variables were analyzed with the MIXED procedure of the SAS statistical software package (SAS for Windows Ver.9.1, SAS Institute Inc., Cary, NC). Factors used in specifying model effects were cultivar, location, block (of the randomized block design), and year (when yearly data rather than averages or cumulative totals over years were analyzed). For data resulting from averaging or totaling over years for each tree, the model included the fixed effects of cultivar and the random effects of location, cultivar × location and block nested within location. For data from yearly observations, this same model was used with the addition of three types of random effects: those for block × cultivar nested within location, those for year nested within location and those for cultivar × year nested within location. In this model the residual is block × year nested within location and cultivar. In both models, the variance of the cultivar × location effects was allowed to differ among cultivars; thus, there was one interaction variance for each cultivar and these are the stability variances whose interpretations are described below (12). The Satterthwaite option (SAS for Windows Ver. 9.1; SAS Institute Inc., Cary, NC) was used for determining degrees of freedom.

The overall objective of the analysis was to compare cultivars across locations, with respect to their means across locations and the consistency of their differences from location to location. The former was done by comparing the cultivar generalized least squares means using pair-wise multiple t-tests, each at the 5% probability level. (Because the means were compared individually by a t test, mean letter designations in Tables 2 to 7 may not follow an alphabetic sequence.) The main source of random error in these comparisons is the random cultivar × location interaction effects. To accomplish the latter, each cultivar had its own variance component for its interaction effects with locations, which is called the stability variance. A stable cultivar is one whose stability variance is zero, indicating that all its inter-

action effects with locations are zero. This would mean that its mean in a given location differs from the mean of all cultivars in that location by an amount that is the same for all locations. Therefore, a stable cultivar is one whose means for a population of locations parallels the means of all cultivars in those locations. Significance of a stability variance estimate was obtained by a one-tailed test based on a normal approximation and tests the hypothesis that the cultivar's stability variance is equal to zero.

Results and Discussion

Tree Survival. In general tree survival at all locations was good; two sites had 100% survival and most of the rest were 90% or higher. The Idaho and Utah sites had relatively high tree losses primarily due to fire blight [*Erwinia amylovora* (Burrill) Winslow et al.] (Table 1). One entire site (Ohio) was removed from the study due to tree loss from this pathogen. Although not statistically analyzed, tree loss by cultivar due to fire blight was greatest for 'Cripp's Pink'.

Flowering. 'Pinova' and 'Cripp's Pink' had the most flower clusters in the first year after planting but were not significantly different from 'Chinook', CQR12T50, 'Golden Delicious', 'Minnewashta', NJ 90 or 'Silken'(Table 2). 'Co-op 29' was the only cultivar that had no flowers the first growing season after planting. Due to the increasing size of the trees, flowering was rated in succeeding years rather than counting the clusters. 'Minnewashta' and 'Pinova' had the highest mean flower ratings of all the cultivars (although they were not significantly different from 'Cripp's Pink'), while 'Co-op 29' had the lowest flower density rating. None of the stability variances for either the number of clusters in 2000 or the overall flowering density ratings were significant, indicating that all the cultivars behaved similarly rela-

Table 1. Survival of trees by site and cultivar

Location	%Survival	Cultivar	%Survival
British Columbia	96.8	Ambrosia	92.0
Idaho	70.0	Autumn Gold	90.0
Massachusetts	91.6	BC 8S-26-50	95.7
New Jersey	98.1	Chinook	88.6
New York - Geneva	97.9	Coop 29	93.3
New York - Ithaca	96.0	Coop 39	92.9
North Carolina	96.0	CQR10T17	96.0
Nova Scotia	98.0	CQR12T50	92.7
Ontario	91.4	Cripp's Pink	85.0
Oregon	99.0	Delblush	96.0
Pennsylvania - Biglerville[z]	90.0	Golden Delicious	89.3
Pennsylvania - Rock Springs	100.0	Hampshire	90.7
Utah	55.8	Jubilee Fuji	92.0
Vermont	97.0	McIntosh	86.7
Washington	99.0	Minnewashta	93.3
West Virginia	89.0	NJ 109	93.3
Wisconsin	100.0	NJ 90	94.7
		NY 65707-19	96.0
		NY 75907-49	92.0
		NY 75907-72	94.7
		Pinova	98.2
		Runkel	98.7
		Silken	92.7

[z] This planting was removed in June of 2004 due to a severe wind storm that destroyed the majority of the remaining trees

Table 2. Means and standard errors (std err.) for number of flowers per tree in 2000 and mean bloom rating of apple cultivars for 2001 through 2004.

Cultivar	Flower clusters in 2000			Mean bloom rating[y] 2001-2004		
	No./tree		std err.	Mean rating		std err.
Ambrosia	8.4	d-i[z]	3.2	3.42	cdefg	0.14
Autumn Gold	7.3	ef	2.3	2.87	hijk	0.19
BC 8S-26-50	2.5	fgi	2.5	2.80	jk	0.16
Chinook	18.7	a-g	6.1	3.55	cdef	0.15
Coop 29	0.0	I	2.2	2.23	l	0.14
Coop 39	15.3	bcde	3.7	3.61	cde	0.15
CQR 10T17	8.5	def	2.8	3.29	efgh	0.14
CQR 12T50	16.4	a-i	5.8	2.53	kl	0.19
Cripp's Pink	32.9	a	3.5	4.11	ab	0.18
Delblush	7.9	ef	2.3	3.52	cdefg	0.14
Golden Delicious	23.8	abc	5.4	3.19	ghij	0.16
Hampshire	16.9	bch	2.3	3.26	efgh	0.17
Jubilee Fuji	5.2	fgi	2.3	2.71	k	0.14
McIntosh	1.8	fgi	4.9	3.17	cdefghijk	0.31
Minnewashta	22.6	ab	4.5	4.30	a	0.14
NJ 109	20.6	abcd	4.6	3.67	cd	0.16
NJ 90	9.0	c-g	3.1	3.66	cd	0.14
NY 65707-19	11.4	b-f	3.1	2.84	ijk	0.16
NY 75907-49	15.2	bcde	3.5	3.37	defg	0.16
NY 75907-72	0.8	gi	2.2	3.23	efghi	0.17
Pinova	37.5	ab	8.7	4.20	a	0.16
Runkel	11.7	bcdefgi	4.5	3.17	fghij	0.18
Silken	22.8	a-g	7.2	3.72	bc	0.16

[z] Means of 17 locations. Those sharing a common letter within each column are not significantly different by a t test at the 5% significance level. Because of imbalanced data and number of replications, the mean separation letters may not run continuously for groupings.

[y] Bloom rated on a scale of 0 = No bloom, 3 = full crop, 5 = snowball bloom

tive to the other cultivars regardless of location.

Tree Size. As measured by TCSA, 'Cripp's Pink' were the largest trees although not significantly different from a number of others and 'Minnewashta' and NY 65707-19 were the smallest, also not significantly different from some other cultivars in 2004 (Table 3). It is interesting that 'Minnewashta' came from the same breeding program that developed 'Honeycrisp' which was the smallest tree in the 1995 NE-183 planting (2). Significant stability variances (P value < 0.05) were found for 'Autumn Gold', 'Co-op 39', CQR10T17, CQR12T50, 'Delblush', NJ 109, NJ 90 and NY 75907-72; indicating that tree size for these cultivars did not behave similarly at all sites in relation to the other cultivars.

At the end of the fifth growing season the tallest trees on average were 'Silken', but were not significantly different from most of the others; there was variability for 'Silken' from site to site as indicated by the significant stability variance. NY65707-19 was the shortest, but not significantly different than eight other cultivars. The trees with the widest canopy spread were 'McIntosh' with several other cultivars not being statistically different. Trees with the narrowest spread were NY 65707-19; three other cultivars did not have significantly different tree spread. NJ 109 was the only cultivar that had a significant stability variance. Four cultivars 'Mc-

Table 3. Means and standard errors (std. err.) for trunk cross sectional area (TCSA), tree height, tree spread and height to spread ratio of apple cultivars in 2004 averaged over all locations.

	TCSA			Height			Spread			Height/Spread		
Cultivar	cm^2		std. err.	m		std. err.	m		std. err	ratio		std. err.
Ambrosia	23.6	gh[y]	3.45	3.09	abc	21.4	1.98	gi	24.6	1.66	ab	0.12
Autumn Gold	**29.9**[z]	bcd	3.87	3.29	a	23.5	2.67	a	25.5	1.35	defg	0.13
BC 8S-26-50	20.6	ij	3.52	2.80	bcd	22.0	2.14	efg	24.7	1.44	cdef	0.12
Chinook	23.9	fgh	3.46	3.06	abc	22.1	2.21	defg	24.8	1.45	bcde	0.12
Co-op 29	30.2	bc	3.54	2.82	bcd	21.4	2.44	abcd	24.6	1.24	fg	0.12
Co-op 39	**28.1**	cde	3.65	3.05	abc	21.5	2.29	cdef	24.6	1.44	cdef	0.12
CQR10T17	**32.4**	abc	3.79	3.17	ab	21.5	2.60	ab	24.6	1.33	defg	0.12
CQR12T50	**20.7**	hij	3.85	2.66	cd	24.1	2.05	fghi	26.6	1.35	defg	0.13
Cripp's Pink	38.0	a	4.84	3.00	abc	25.0	2.49	a-e	28.6	1.26	defg	0.14
Delblush	**33.3**	ab	3.84	3.03	abc	21.3	2.41	abcd	24.5	1.32	defg	0.12
Golden Delicious	30.8	bc	3.52	2.91	abc	21.5	2.31	cdeg	24.6	1.33	defg	0.12
Hampshire	25.4	efg	3.49	2.80	bcd	21.5	2.43	abcd	24.6	1.25	efg	0.12
Jubilee Fuji	29.7	bc	3.53	2.90	abcd	21.4	2.62	a	24.6	1.18	g	0.12
McIntosh	34.1	a-j	9.93	3.08	abcd	49.4	2.74	abcd	35.7	1.01	defg	0.26
Minnewashta	19.3	j	3.53	3.11	abc	21.5	2.06	fg	24.6	1.61	abc	0.12
NJ 109	**33.0**	abc	4.16	2.96	abc	21.3	**2.49**	a-g	41.1	1.42	cdef	0.12
NJ 90	**23.1**	fghi	3.66	2.89	abc	21.3	2.49	abc	24.5	1.26	efg	0.12
NY 65707-19	15.5	j	4.40	2.46	d	23.5	1.73	i	26.3	1.65	abc	0.15
NY 75907-49	22.7	hi	3.49	2.72	cd	23.9	2.28	cdef	25.6	1.33	defg	0.13
NY 75907-72	**21.2**	hij	3.63	2.92	abc	21.4	2.00	fghi	27.8	1.78	a	0.16
Pinova	26.5	def	3.56	2.88	abcd	21.8	2.13	efg	24.7	1.47	bcd	0.12
Runkel	25.5	efg	3.45	2.93	abc	21.4	2.39	bcd	24.6	1.30	defg	0.12
Silken	29.2	bcd	3.68	**4.06**	abc	78.8	2.52	abc	25.0	1.71	a-g	0.34

[z] Bold typeface denotes the stability variance for that mean was significantly different from zero indicating differential performance by site, P value < 0.05. Because of imbalanced data and number of replications, the mean separation letters may not run continuously for groupings.

[y] Means of 17 locations. Those sharing a common letter within each column are not significantly different by a t test at the 5% significance level.

Intosh', 'Autumn Gold', 'Jubilee Fuji' and CQR10T17 exceeded the allotted in-row spacing of 2.5 m while most other cultivars were contained within their allotted space or were under it. NY 75907-72 had the highest average H:S ratio, indicating that the trees were taller than wide; while 'McIntosh' were just about as wide as they were tall. None of the cultivars had a significant H:S stability variance.

Traditionally tree size has been compared by TCSA (8). TCSA was utilized in this study as well, but there was a case where more tree measurements might be needed. 'Minnewashta' and NY65707-19 had similar TCSA but 'Minnewashta' tree height and canopy spread were significantly larger than those of NY65707-19. It maybe important when specifically evaluating new cultivars that mean tree height and spread are determined as well as TCSA.

Yield, Efficiency, Number of Fruit and Biennial Bearing Index. CQR10T17 had the highest CY but it was not significantly better than seven other cultivars (Table 4). The lowest yielding cultivars were NY 75907-72, NY65707-19 and NJ 109. Some of the cultivars had stability variances that were significantly different from zero, including 'Autumn Gold', 'Chinook', 'Co-op 29', CQR10T17, 'Golden Delicious', 'Hampshire', 'Jubilee Fuji', NY 75907-49, 'Pinova' and 'Silken'. This indicates that at certain locations the CY of that cultivar was higher or lower in relation to the other cultivars, meaning that the cultivar may perform better or worse at a particular site. In general CY at NYG site was the highest and CY at WA was the lowest (data not shown). The highest CY for 12 of the 23 cultivars occurred at NYG. The NYI and PAR sites both had 4 cultivars with the highest CY. The WA site had 10 cultivars that had the lowest CY.

'Pinova' had the highest CYE but was not significantly better than nine other cultivars (Table 4). Two numbered selections, NJ 109 and NY75907-72 had the lowest CYE and this was true at all sites since the stability variance was not significant. Cultivars with significant stability variances included 'Chinook', 'Co-op 39', CQR10T17, 'Golden Delicious', NY 65707-19, 'Runkel' and 'Silken' indicating CYE varied by site. Lafer (7) suggested that annual yield efficiencies should be in the range of 1.0 to 1.5 $kg \cdot cm^{-2}$ of trunk cross-sectional area. Only NJ 109 and NY75907-72 did not reach the minimum threshold, but 16 cultivars exceeded the suggested maximum level.

The two named cultivars from British Columbia, 'Chinook' and 'Silken' tended to have the highest number of fruit per tree over the entire study. NY 75907-72 produced on average the lowest number of fruit per tree. The growth habit of this cultivar had less branching and a more spur-like growth pattern with considerable blind wood. Cultivars that had significant stability variances that indicated they did not perform uniformly at all sites included 'Autumn Gold' 'Chinook', CQR10T17, 'Golden Delicious' 'Jubilee Fuji', NJ 90, 'Pinova', and 'Silken'. Since the number of fruit is largely influenced by the amount, and quality of thinning it is possible that individuals may have varied their degree of thinning.

The tendency for a cultivar to become biennial can be partially a result of inadequate fruit thinning. The BI is a means to measure this tendency. Values over 0.6 indicate that the cultivar has a strong tendency towards biennial bearing (11). 'Autumn Gold', BC 8S-26-50, 'Co-op 29', CQR12T50, and 'Jubilee Fuji' all had an index above the desired threshold. These cultivars will need early and heavy thinning to prevent biennial bearing. Cultivars with significant stability variances included 'Autumn Gold', 'Chinook' 'Golden Delicious', 'Jubilee Fuji' and 'Hampshire'. The significant stability variance would indicate that the tendency for a cultivar to be biennial or not varied by site. Since 'Autumn Gold' and 'Jubilee Fuji' had BI values ≥ 0.60 they were not consistently biennial and adequate early season intervention may prevent biennial bearing. With the other three

Table 4. Means and standard errors (std. err.) for cumulative yield, cumulative yield efficiency, average number of fruit per year and biennial bearing index of apple cultivars in the 1999 NE-183 planting.

	Cumulative yield			Cumulative yield efficiency			Mean number of fruit/year			Biennial bearing index		
Cultivar	kg		std. err.	kg•cm^{-2}		std. err.	count		std. err.	index		std. err.
Ambrosia	31.6	ghi[y]	4.59	1.60	cdf	0.14	40.8	ef	6.7	0.59	bcf	0.04
Autumn Gold	**46.8**[z]	abcd	6.02	1.72	abcd	0.18	**59.2**	bc	7.9	**0.60**	a-e	0.08
BC 8S-26-50	30.2	hij	4.43	1.51	cde	0.17	35.0	fg	6.4	0.61	abcd	0.06
Chinook	**43.7**	a-e	5.76	**1.96**	ab	0.19	**88.9**	a	13.6	**0.48**	defg	0.06
Co-op 29	**33.0**	fghi	4.98	1.15	hi	0.15	41.8	ef	6.8	0.72	a	0.05
Co-op 39	29.0	hijk	4.52	**1.25**	eghi	0.18	40.2	ef	6.7	0.50	cdeg	0.05
CQR10T17	**60.3**	a	9.34	**1.96**	abcd	0.22	**67.8**	abc	10.9	0.47	eg	0.04
CQR12T50	34.8	d-i	5.86	1.81	abcd	0.22	48.6	cde	7.4	0.70	ab	0.07
Cripp's Pink	42.5	a-i	8.32	1.25	efhi	0.17	66.3	a-f	13.0	0.44	defg	0.07
Delblush	40.3	b-f	4.90	1.28	eh	0.15	59.5	bc	7.4	0.49	eg	0.05
Golden Del.	**51.8**	a	5.37	**1.88**	abcd	0.19	**75.2**	a	8.0	**0.55**	bcde	0.06
Hampshire	**40.8**	b-f	5.16	1.82	abc	0.16	51.6	cd	6.6	**0.54**	cde	0.06
Jubilee Fuji	**45.9**	abc	4.92	1.69	bcd	0.14	**60.4**	bc	7.1	**0.62**	abc	0.06
McIntosh	33.8	e-i	5.28	1.31	a-j	0.29	43.9	def	7.7	0.52	abcdeg	0.07
Minnewashta	27.1	ljk	4.55	1.54	dfg	0.15	35.3	fg	6.4	0.41	g	0.05
NJ 109	22.2	kl	4.99	0.85	j	0.16	27.8	gh	6.8	0.49	eg	0.05
NJ 90	34.7	efgh	4.94	1.77	a-e	0.28	**48.0**	cde	7.7	0.50	de	0.04
NY 65707-19	22.0	jkl	5.22	**1.83**	a-e	0.27	29.4	gh	6.9	0.52	bcdeg	0.08
NY 75907-49	**36.0**	c-i	5.68	1.67	bcd	0.18	39.6	efg	7.6	0.58	bcde	0.07
NY 75907-72	18.1	l	4.45	0.99	ij	0.15	22.1	h	6.5	0.48	eg	0.04
Pinova	**49.1**	ab	5.66	2.05	a	0.17	**66.2**	ab	8.5	0.42	g	0.04
Runkel	39.9	b-f	4.76	**1.68**	bcd	0.17	43.7	ef	6.6	0.58	bcf	0.05
Silken	**50.6**	a-g	9.72	**1.94**	abcd	0.28	**88.8**	a-e	22.8	0.48	defg	0.06

[z] Bold typeface denotes the stability variance for that mean was significantly different from zero indicating differential performance by site, P value < 0.05. Because of imbalanced data and number of replications, the mean separation letters may not run continuously for groupings.

[y] Means of 17 locations. Those sharing a common letter within each column are not significantly different by a t test at the 5% significance level.

cultivars, 'Chinook', 'Golden Delicious' and 'Hampshire', they may have biennial bearing tendencies.

Average Fruit Weight, Pre-harvest Fruit Drop and Crop Load. Average FW from NY 75907-49 was the greatest, followed by 'Runkel' (Table 5). Apart from these two cultivars there were six others that had significantly larger fruit than 'Golden Delicious'. The smallest fruit were those from 'Chinook' and, as grown in the eastern U.S., would not be acceptable. However we cannot determine for certain if the small fruit size of 'Chinook' is a natural tendency or was due to insufficient thinning in this study. 'Chinook' has a tendency to overset fruit; if it is not thinned hard and early, fruit size remains small (13). Since 'Chinook' had the highest average number of fruit per tree it seems probable size would increase with appropriate fruit thinning. Based upon a weight to box count size table (16) the 'Chinook' would have graded out at 150 count fruit; while 'Cripp's Pink' and 'Silken' would have been 113 count fruit. NY 75907-49 average fruit weight would have graded out as 80 count fruit.

Pre-harvest fruit drop that equals or exceeds 20% may limit the economic viability of a cultivar and may pose problems in timing harvest. In most cases the percent drop was below the threshold value. NJ 90, NY 65707-19 and NY 75907-49 all had a mean percent drop in excess of 20%, although they did not perform in a similar fashion at all sites because they had significant stability variances. In addition ten other cultivars had significant stability variances. 'Silken' had the lowest percent drop of all the cultivars.

CL varied among cultivars. The number of fruit per cm^2 of trunk cross sectional area was highest for 'Chinook' and lowest for NJ 109 and NY 75907-72. Only 'Chinook' exceeded the maximum crop load threshold of 6-9 fruits cm^{-2} suggested by Lafer (8). With the exception of the standard ,'Golden Delicious', none of the cultivars was the same in the 1995 and 1999 plantings; most of the cultivars in the 1999 planting had an overall lower CL. Mean crop load for 'Golden Delicious' was lower in this planting than in the previous planting. The heavy crop load for 'Chinook' and 'Silken' coincided with small fruit size. It was unfortunate that neither of these cultivars was planted at the BC site since they were both developed there (13,14). It should be noted that all three of the cultivars developed in BC had significant stability variances for CL, indicating that there were some sites where these cultivars performed differently or were thinned better.

Bloom Date, Date of Harvest and Number of Days from Bloom to Harvest. 'Minnewashta' and 'Silken' were the earliest blooming cultivars, while 'Runkel' bloomed the latest, although it was not significantly different from 5 other cultivars (Table 6). A late blooming cultivar may be advantageous in avoiding early spring frosts and is a breeding objective in some breeding programs (9). The earliest maturing cultivar was 'Minnewashta' while 'Cripp's Pink' was the latest. Thirteen cultivars matured before 'Golden Delicious' and nine matured after. While 'Cripp's Pink' was planted in some of the more northern regions of the country it is doubtful that this cultivar can be matured to an acceptable consumer quality in some of those regions since it required on average about 183 days to properly mature. 'Ambrosia', 'Runkel', NY65707-19 and 'Hampshire' were harvested in the same time frame as 'Golden Delicious' at around 150-155 days after full bloom.

The range of days from bloom to harvest varied by site (Table 7). 'Golden Delicious' had the smallest range in dates. Idaho and Oregon had sixteen cultivars with the longest time to fruit maturity in comparison to the other sites. Wisconsin had fifteen cultivars with the fewest days from bloom to harvest. It is interesting to note that in both this planting and the previous one (2) warmer regions consistently required more days from bloom to harvest than the more northern sites. Possibly in these cooler regions, maturity is accelerated by early stimulation of ethylene synthesis with cold temperatures, a phenomenon

Table 5. Means and standard errors (std. err.) for average fruit weight percent pre-harvest fruit drop and average crop load of apple cultivars in the 1999 NE-183 planting.

	Avg. fruit weight			Fruit drop			Crop load (no.•cm^{-2} TCSA)		
Cultivar	g		std. err.	%		std. err.	Mean		std. err.
Ambrosia	199.0	fghy	8.5	10.0	fghi	1.71	2.93	f	0.37
Autumn Gold	210.6	def	9.1	**13.5**	defg	2.36	3.63	cde	0.40
BC 8S-26-50	220.0	d	9.4	**12.2**	efgh	2.24	**2.83**	fg	0.43
Chinook	129.4	m	8.3	9.6	fghi	1.79	**6.10**	a	0.69
Co-op 29	**212.4**[z]	def	11.1	9.2	ghi	1.56	2.39	g	0.39
Co-op 39	183.9	ij	9.1	**8.7**	ghi	1.89	**2.55**	fg	0.41
CQR10T17	234.2	bc	8.1	**14.7**	cdef	2.64	2.85	fg	0.38
CQR12T50	**200.9**	d-i	12.8	8.0	hi	1.93	**4.72**	abcd	0.69
Cripp's Pink	**148.9**	l	8.8	7.9	hi	1.63	3.77	b-g	0.67
Delblush	174.2	jk	9.2	**18.8**	abcd	2.82	**3.03**	ef	0.40
Golden Delicious	**183.3**	ij	8.6	**12.9**	defg	2.19	**4.44**	b	0.45
Hampshire	**220.8**	cd	9.8	**15.7**	bcde	2.41	**3.78**	bcd	0.41
Jubilee Fuji	201.1	efg	9.0	7.2	ij	1.58	3.59	cdh	0.37
McIntosh	**190.1**	f-j	10.2	10.6	efghi	2.26	2.47	fghi	0.46
Minnewashta	189.6	ghij	9.9	**11.5**	efgh	2.01	2.78	fg	0.36
NJ 109	**189.8**	ghij	10.3	9.0	ghi	1.67	1.57	i	0.39
NJ 90	187.0	i	8.3	**25.1**	a	3.17	**3.23**	defg	0.56
NY 65707-19	220.8	bcde	11.3	**22.3**	abc	3.33	3.38	def	0.49
NY 75907-49	254.4	a	10.0	**20.8**	ab	2.03	2.79	fg	0.40
NY 75907-72	200.7	efgh	9.1	**13.2**	defg	2.31	1.60	i	0.38
Pinova	**189.9**	hi	8.2	6.7	hij	2.19	4.09	bcd	0.40
Runkel	**240.7**	ab	9.8	**12.3**	efg	1.80	**2.94**	fg	0.40
Silken	**158.2**	kl	10.6	4.1	j	1.63	**5.14**	abc	0.77

[z] Bold typeface denotes the stability variance for that mean was significantly different from zero indicating differential performance by site, P value < 0.05. Because of imbalanced data and number of replications, the mean separation letters may not run continuously for groupings.

[y] Means of 17 locations. Those sharing a common letter within each column are not significantly different by a t test at the 5% significance level.

Table 6. Means and standard errors (std. err.) for calendar day of full bloom and harvest and days from full bloom to harvest (DAFB) for apple cultivars in the 1999 NE-183 planting.

Cultivar	Calendar day of full bloom		std.err.	Calendar day of harvest		std.err.	DAFB		std.err.
Ambrosia	124.3	cde[z]	3.20	**273.2**	ghi	2.51	151.2	ef	2.31
Autumn Gold	123.0	h	3.20	284.3	cd	2.48	161.1	c	2.28
BC 8S-26-50	124.5	bcd	3.21	**280.5**	de	2.59	156.1	d	2.44
Chinook	123.8	defg	3.20	**289.7**	b	2.79	**166.8**	b	3.12
Co-op 29	124.1	de	3.21	287.5	bc	2.42	163.4	bc	2.56
Co-op 39	124.9	abc	3.20	263.2	j	2.39	139.0	j	2.49
CQR10T17	124.1	cde	3.21	270.2	i	2.32	146.4	ghi	2.45
CQR12T50	125.0	ab	3.20	255.4	kl	2.80	130.7	kl	3.15
Cripp's Pink	123.2	defghi	3.26	**304.5**	a	3.56	183.2	a	3.56
Delblush	123.2	gh	3.20	283.1	d	2.18	160.1	c	2.20
Golden Delicious	124.6	abcd	3.21	275.4	fgh	2.41	152.0	e	2.30
Hampshire	**123.4**[y]	efgh	3.21	**278.3**	ef	2.75	**154.2**	def	3.14
Jubilee Fuji	124.0	def	3.20	**268.5**	hij	3.88	**143.3**	hij	3.62
McIntosh	122.8	a-i	3.30	250.2	b-n	7.06	122.9	a-m	9.69
Minnewashta	122.2	i	3.21	**232.7**	n	2.60	111.7	m	2.60
NJ 109	**123.7**	defgh	3.22	251.9	lm	2.29	128.8	l	2.60
NJ 90	124.5	abcd	3.21	**270.7**	i	2.55	**146.3**	ghi	2.61
NY 65707-19	124.1	de	3.20	277.9	efg	2.59	153.4	de	2.54
NY 75907-49	123.2	fgh	3.21	263.9	j	2.48	141.8	ij	2.68
NY 75907-72	123.9	def	3.20	257.0	k	2.21	133.5	kl	2.20
Pinova	123.9	defgh	3.22	271.8	i	2.21	148.5	fgh	2.27
Runkel	**125.6**	a	3.22	**276.8**	efg	2.49	150.7	efg	2.50
Silken	121.9	i	3.22	**248.7**	m	2.80	127.5	l	3.09

[z] Bold typeface denotes the stability variance for that mean was significantly different from zero indicating differential performance by site, P value < 0.05. Because of imbalanced data and number of replications, the mean separation letters may not run continuously for groupings.
[y] Means of 17 locations. Those sharing a common letter within each column are not significantly different by a t test at the 5% significance level.

Table 7. Mean days from full bloom to harvest by location of apple cultivars in the 1999 NE-183 planting

Cultivar	BC[z]	ID	MA	NC	NJ	NYG	NYI	ON	OR	PAR	UT	VT	WI	WV	Range[y]
Ambrosia	150	160	143	150	166	165	149	135	172	149	150	141	134	150	134-172
Autumn Gold	163	160	151	168	182	160	.	156	177	.	160	.	147	155	147-182
BC 8S-26-50	.[x]	158	143	155	168	168	153	155	177	156	158	153	143	146	143-177
Chinook	.	164	159	189	183	167	162	152	183	170	161	154	151	165	151-189
Co-op 29	172	164	157	173	170	167	156	156	169	164	170	160	146	167	146-173
Co-op 39	136	152	131	145	148	146	136	138	143	131	.	140	132	137	131-152
CQR10T17	153	164	136	153	147	144	140	138	161	136	142	146	136	145	136-164
CQR12T50	125	150	129	140	140	133	129	.	.	.	126	114	.	125	114-150
Cripp's Pink	184	194	.	196	.	.	.	.	190	184	186	.	151	183	151-196
Delblush	169	165	151	160	163	162	155	155	175	154	163	157	148	158	148-175
Golden Delicious	150	159	148	162	159	147	152	141	160	147	154	147	144	151	144-160
Hampshire	160	174	150	155	165	165	149	120	156	154	166	139	141	159	120-174
Jubilee Fuji	139	162	133	143	153	132	146	155	183	136	139	128	126	136	126-183
McIntosh	.		.	.	140	.	.	106	.	.	.	.	.	.	106-140
Minnewashta	112	134	109	104	113	114	113	98	120	110	110	111	100	109	98-134
NJ 109	136	139	126	122	132	132	130	128	134	124	126	118	125	123	118-139
NJ 90	145	150	146	143	140	156	144	141	165	148	140	138	129	154	129-156
NY 65707-19	163		.		170		147	138	171	152	153	143	136	.	136-170
NY 75907-49	137		.	142	142		145	141		145	149	131	127	137	127-149
NY 75907-72	138	147	126	131	136	132	130	128	151	130	136	129	119	126	119-151
Pinova	152	159	139	152	.	149	148	141	156	150	.	143	.	.	139-159
Runkle	158	152	143	151	154	164	152	155	172	140	151	141	140	145	140-172
Silken	.	144	128		136	124	122	107	129	126	.	123	118	130	107-144

[z] Locations are given in Table 1 and are abbreviated here
[y] Range represents the earliest and latest mean days from bloom to harvest across all locations
[x] A period indicates this site did not receive a particular cultivar

reported to occur in Australia with 'Fuji' and other late maturing cultivars (6). In comparison to the previous study (2) the average days from full bloom for 'Golden Delicious' increased in nine out of ten sites that had both the 1995 and 1999 plantings.

It is clear that no one cultivar was outstanding in all the parameters measured. The ultimate determinant for the success of a new cultivar lies largely with the acceptance by the consuming public (3) as well as the ability to mature the fruit to a level that is acceptable in the market place. However, there were some cultivars that performed better than others. NY 75907-72 had the lowest cumulative yield, number of fruit per tree and a low mean crop load. Individual fruit weight of this cultivar was in the middle of the rankings. 'Pinova' on the other hand, had the highest yield efficiency, good cumulative yield and average number of fruit, a low biennial bearing index and low pre-harvest drop. Fruit size, although in the middle of the group, was still acceptable about 113 count. 'Chinook' had a high yield efficiency but fruit size was so low that this cultivar probably can only be grown with early and heavy fruit thinning to increase fruit size.

There were fewer outstanding cultivars in this planting than in the previous planting. However, some of the cultivars are slowly gaining a commercial reputation often under a different trademarked name or exclusive marketing agreement including 'Ambrosia', 'Cripp's Pink' (Pink Lady®), 'Delblush' (Tentation™) and 'Pinova' (Piñata™). Other cultivars with regional or local appeal include 'Hampshire', 'Silken' and 'Minnewashta' (Zestar!™). Of the disease resistant cultivars in the planting, only two have been released to the public, 'Co-op 29' (Sundance™) and 'Co-op 39' (Crimson Crisp™). They were about equal in horticultural performance, although 'Co-op 29' did exhibit a strong tendency toward biennial bearing.

The use of 'Golden Delicious' as a standard was primarily based on its universality of planting, being the third most important cultivar in the world. However, 'Golden Delicious' had significant stability variances for CY, CYE, BI, NF, FW, %DF and CL and may not be an ideal cultivar to utilize.

Literature Cited

1. Blanpied, G. D. and K. J. Silsby. 1992. Predicting harvest date window for apples. Cornell Coop. Ext. Publ. Info. Bull. 221.
2. Crassweller, R., R. McNew, A. Azarenko, B. Barritt, R. Belding, L. Berkett, S. Brown, J. Clemens, J. Cline, W. Cowgill, D. Ferree, E. Garcia, D. Greene, G. Greene, C. Hampson, I. Merwin, D. Miller, S. Miller, R. Moran, J. Obermiller, D. Rosenberger, C. Rom, T. Roper, J. Schupp and E. Stover. 2005. Performance of apple cultivars in the 1995 NE-183 regional project planting: I. Growth and yield characteristics. J. Amer. Pomol. Soc. 59:18-27.
3. Greene, D. W. 2005. NE-183 regional project: consumer survey of some of the most promising new apple varieties. Fruit Notes 70(3): 1-6.
4. Greene, D. W. 2007. Multidisciplinary evaluation of new apple cultivars: the NE-183 regional project 1999 planting. J. Amer. Pom. Soc. 61: 78-83.
5. Huang, S. W. and F. Gale. 2006. China's rising profile in the global market for fruits and vegetables. AmberWaves USDA Economic Research Service located at http://www.ers.usda.gov/AmberWaves/April06/DataFeature/ as accessed on August 22, 2006.
6. Jobling, J., R. Pradhan, S. C. Myers and N. L. Wade. 2003. Induction of chill-induced ripening in Fuji apples is a function of both temperature and time. Aust. J. Exp. Agr. 43:1255-1259.
7. Lafer, G. 1999. Fruit ripening and quality in relation to crop load of apple trees. Pp. 369-372. In: M. Hägg, R. Ahvenainen, A. M. Evers and K. Tiikikkala (eds). Agri-food quality II: quality management of fruits and vegetables. The Royal Society of Chemistry. Cambridge, UK.
8. Lombard, P., N. W. Callahan, F. G. Dennis, Jr., N. E. Looney, G. C. Martin, A. R. Renquist and E. A. Mielke. 1988. Towards a standardized nomenclature, procedures, values and units in determining fruit and nut tree yield and performance. HortScience 23:813-817.
9. Miller, D. D. 2004. Evaluation of Malus sieversii seedlings from Kazakhstan for disease resitance and time of leafing. Acta Hort. 663:535-537.
10. O'Rourke, D., J. Janick and S. Sansavini. 2003. World apple cultivar dynamics. Chronica Hort. 43(3):10-13.

11. Pearce, S. C. and S. Debusek-Urbanc. 1967. The measurement of irregularity in growth and cropping. J. Hort. Sci. 42:295-305.
12. Piepho, H. P. 1999. Stability analysis using the SAS system. Agron. J. 91:154-160.
13. Quamme, H. A., R. A. MacDonald, W. D. Lane and C. R. Hampson. 1999. Chinook apple. Can. J. Plant Sci. 79:291-294.
14. Quamme, H. A., R. A. MacDonald, W. D. Lane and C. R. Hampson. 1999. Silken apple. Can. J. Plant Sci. 79:295-297.
15. Way, R., H.S. Aldwinckle, R. C. Lamb, A. Rejman, S. Sansavini, T. Shen, R. Watkins, M. Westwood and Y. Yoshida. 1990. Apples (*Malus*). In: Genetic resources of temperate fruit and nut crops. J. N. Moore and J. R. Ballington (eds). Acta Horticulturae 290:1-67.
16. Zhang, J. G. F. Thiele and R. N. Rowe. 1995 Gala apple fruit size distribution. NZ J. Crop Hort. Sci. 23:85-88.

❖ ❖ ❖ ❖ ❖

CALL FOR PAPERS – U.P. HEDRICK AWARD

A cash award of $300 with mounted certificate will be awarded to the winning student paper. Papers should be submitted to Dr. Esmaeil Fallahi, University of Idaho, Parma Research and Extension Center, 29603 U of I Lane, Parma ID 83660-6699 (e-mail: efallahi@uidaho.edu) by May 30, 2007. See the Journal for editorial style; paper length about 1000 words or 3-4 pages total. Papers can relate to any research aspect with fruit cultivars or rootstocks as influenced by environmental or cultural techniques. Breeding or the history or performance of new or old cultivars can be reviewed. Research and review papers will be judged separately.