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Performance of Apple Cultivars in the 1999 NE-183 Regional Project Planting. III. Fruit Sensory Characteristics

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Abstract

The sensory qualities of a new apple (*Malus* x *domestica* Borkh.) cultivar are central to its consumer acceptance. This study examined the crispness, juiciness, sweetness, acidity, flavor, attractiveness and commercial desirability of 23 new cultivars and breeding selections at nine locations across the United States. The commercial standard of comparison for the study was 'Golden Delicious'. The fruit from four or five replicate trees per cultivar were rated on 5-point scales within 7 days of harvest at each site for 4 consecutive years. All sensory aspects of the cultivars were differentially affected by the influence of growing location, but some broad trends were observed. Selections that scored high for crispness at a majority of sites were CQR10T17, 'Co-op 39' (Crimson Crisp™), 'Silken', 'Ambrosia', 'Co-op 29' (Sundance™), CQR12T50 and NY 65707-19. All selections were rated acceptable or higher for juiciness at most locations. 'Ambrosia', BC 8S-26-50 and 'Golden Delicious' were considered high in sweetness at most locations, and 'Cripp's Pink' (Pink Lady®), NJ 109 and all the scab-resistant clones were significantly less sweet than 'Golden Delicious' at most locations. 'Fuji' (September Wonder®), 'Ambrosia', BC 8S-26-50 and 'Runkel' tended to be low in acidity, and 'Cripp's Pink', 'Delblush' (Tentation®), 'Pinova', 'Co-op 29', 'Co-op 39', CQR12T50 and CQR10T17 were high in acidity. Flavor ratings were highly inconsistent across locations, but 'Ambrosia' and 'Minnewashta' (Zestar!®) were liked, and CQR10T17 was disliked at a majority of sites. The most consistently attractive selections were 'Ambrosia', NY 79507-72, 'Cripp's Pink' and 'Pinova', and the least attractive were 'Golden Delicious', 'Co-op 29' and BC 8S-26-50, probably due to skin russet. For most cultivars, desirability varied from location to location, but 'Ambrosia', 'Pinova' and CQR12T50 were rated highly at all reporting locations. The results reinforce the importance of widespread systematic testing of new cultivars.

Consumers today enjoy year-round availability of a greater choice of fresh fruit than ever before. A diversity of the product (appearance, flavor) and high eating quality are keys to maintaining apple consumption in a competitive global marketplace. Consumers may seek a diverse range of apple flavor and appearance, but they usually demand firm, crisp and juicy texture. Apple producers are seeking productive, profitable new cultivars that are easy to grow, adapted to their climate and management practices, with good color, fruit size and skin finish, and preferably a reduced need for sprays. Apple cultivars differ greatly in pest and disease susceptibility (1,7,8,9), sensory quality before and after storage (6,10), cold hardiness (14) and many other aspects. They also vary in the stability of their performance across locations, with respect to both fruit quality (12) and horticultural performance (3). Therefore, there is a need for systematic cultivar testing across a variety of locations. The NE-183 regional project entitled "Multidisciplinary evaluation of new apple cultivars" was initiated to do such testing, with the goal of reducing business risk to producers by identifying the cultivars that perform best in different production regions.

The objective of this report is to examine the sensory qualities of 23 new apple cultivars and breeding selections, and the consistency of their sensory quality among growing locations across the USA. The sensory as-

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pects chosen for study (crispness, juiciness, sweetness, acidity, attractiveness, flavor and overall desirability) would influence the consumer acceptability of these new apples. Reports on the horticultural performance (4) and objective measurements of fruit quality (13) of these same cultivars are available.

Materials and Methods

A total of 23 cultivars were propagated, including 'Golden Delicious' (Gibson strain) as a reference cultivar. For a complete listing with parentages, see Greene et al. (5). All trees were propagated by Wafler's Nursery (Wolcott, NY) on M.9 rootstock. Because of a shortage of certain cultivars, not all sites received all cultivars. The trees were planted in the spring of 1999, at a tree spacing of 2.5 m x 4.3 m, with the bud union 5 cm above the soil line. 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. Pruning was minimized to allow each tree to express its natural growth habit. Pest management, irrigation and fertilization followed local recommendations, except that no calcium was applied, in order to detect any cultivar propensities for calcium-related disorders. The trees were first cropped in year 2 or 3, at the cooperator's discretion. The fruit were thinned to a spacing of 15-20 cm.

Fruit were harvested when starch index (SI) reached 4 to 6 on the 8-point Cornell University starch-iodine index chart (2). Data for a given cultivar-location-year were excluded from statistical analysis if the mean SI was lower than 3.5 or higher than 6.5. Five apples per replicate tree that were representative of the cultivar for size, appearance and maturity were used for sensory evaluation. If fewer than five fruit were available, a composite sample from several replicate trees was used. Apples were stored at 1-5 ºC and brought to room temperature (21-25 ºC) before evaluation if tasting could not be done on the day of harvest. The fruit surface was lightly buffed with a soft towel before evaluating the appearance, to remove any dust, bloom or other surface residues.

Seven sensory attributes were rated by a single person at each site: attractiveness of external appearance, overall commercial desirability, flavor, crispness, juiciness, acidity and sweetness. Definitions of these attributes were published previously (10). A bipolar five-point hedonic scale was used to rate attractiveness, desirability and flavor, where 1=dislike, 2=fair, 3=acceptable, 4=good, 5=like very much. A unipolar scale of 1 (low) to 5 (high) was used to evaluate crispness, juiciness, sweetness and acidity. Cooperators at nine sites participated in this study (Table 1).

Most cooperators defruited the trees in 2000 to encourage tree growth. Data from 2001 to 2004 inclusive were analyzed with

Table 1. Locations and cooperators who submitted fruit sensory evaluation data.

Location	Cooperator	Planting Location
(MA) Massachusetts	Duane Greene	Belchertown
(NJ) New Jersey	Win Cowgill	Pittstown
(OR) Oregon	Anita Azarenko	Corvallis
(PAB) Pennsylvania	George Greene II	Biglerville
(PAR) Pennsylvania	Rob Crassweller	Rock Springs
(UT) Utah	Thor Lindstrom	Kaysville
(VT) Vermont	M. Elena Garcia[z], Lorraine Berkett	Burlington
(WI) Wisconsin	Matt Stasiak	Sturgeon Bay
(WV) West Virginia	Stephen Miller	Kearneysville

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the SAS statistical software package (release 8.2, SAS Institute, Cary NC), using a mixed linear model (MIXED procedure). The Satterthwaite option was used for determining the degrees of freedom, and estimates of the variance components for random effects were REML estimates. Location, cultivar and their interaction were deemed fixed effects. Block, replicate nested within cultivar, year, and all interaction terms that included year, were considered random effects. Generalized least squares means for cultivar within location were compared if the p value of the F test for cultivar x location was less than 0.01. Pairwise comparisons were made with multiple t tests, each using a significance level of 0.05. No LSD can be given because all comparisons have different standard errors.

Results and Discussion

For crispness, desirability and flavor, the location effect was not significant, but cultivar and cultivar x location effects were highly significant ($p < 0.0001$). For all other response variables, both main effects and the interaction between cultivar and location were significant. Significant interaction means that location affected all the sensory attributes differentially across cultivars. The following discussion therefore focuses on results within a location, and broad commonalities. Tables 2-8 show two-way means, with mean separation within site indicated.

Attribute intensity ratings. Genotypes rated among the highest for crispness at most of the sites where they were planted were: 'Ambrosia', CQR10T17, 'Co-op 39', 'Co-op 29', 'Silken', NY 65707-19 and CQR12T50 (Table 2). Nearly all cultivars were rated at least 3.0 (moderately crisp) at most locations, including 'Golden Delicious'. Only 'McIntosh' (one site), NJ 109 (4 of the 9 sites) and 'Runkel' (5 of the 9 sites) tended to score below 3.0. Flesh crispness and firmness are correlated but distinguishable attributes (6); 'Cripp's Pink' and 'Chinook' are examples of apples that were very firm in this study (13), but not necessarily crisp.

All cultivars were rated at least 3.0 (moderately juicy) on average across locations (data not shown), but none rated as high as 5.0 (extremely juicy), so the range for juiciness rating was limited. BC 8S-26-50 scored 4.0 or higher at five sites (Table 3). 'Golden Delicious' was rated medium in juiciness at many of the locations. 'Co-op 39' seemed to be the juiciest scab-resistant apple, although it scored low for juiciness in WI. In general, ratings for juiciness were inconsistent from location to location. For example, 'Cripp's Pink' was among the least juicy at several locations, especially OR, yet was considered very juicy at the PAB site. CQR12T50 was planted at only three sites, yet its juiciness scores were inconsistent.

Sweetness scores were also variable from site to site. This inconsistency extended to the standard cultivar: in NJ, UT and WI, 'Golden Delicious' ranked the highest in sweetness, whereas elsewhere it usually fell into the middle of the cultivar range (Table 4). 'Ambrosia' and BC 8S-26-50 were rated significantly sweeter than 'Golden Delicious' at many sites. The soluble solids content (SSC) of these two cultivars was similar to or lower than 'Golden Delicious' but they also tended to be low in titratable acidity (13). Cultivars significantly less sweet than 'Golden Delicious' were 'Cripp's Pink' (all 6 sites), 'Co-op 29' (all 8 sites), CQR10T17 (8 of 9 sites), NJ 109 (all 8 sites), NY 65707-19 (6 of 7 sites). 'Delblush' also scored significantly lower in sweetness than 'Golden Delicious' at six sites, and nowhere was it considered sweeter than 'Golden Delicious'. In objective measurements, 'Delblush' has similar SSC to 'Golden Delicious' but is significantly higher in titratable acidity (13).

'Fuji' (Jubilee strain), 'Ambrosia', BC 8S-26-50 and 'Runkel' were all considered significantly less acidic than 'Golden Delicious' at a majority of locations (Table 5), whereas 'Cripp's Pink' was among the most acidic (and significantly more acidic than 'Golden Delicious') at five of the six sites where it was planted. 'Delblush' (8 of 9 sites) was also

Table 2. Generalized least-squares means for sensory crispness ratings among 23 apple cultivars grown at nine planting locations for the years 2001 through 2004.

Cultivar	Mean crispness rating[z]								
	MA[y]	NJ	OR	PAB	PAR	UT	VT	WI	WV
Ambrosia	4.3[x] abc	4.5 a	3.3 h	4.0 a	3.5 de	3.8 bcd	3.3 a-f	4.7 a	3.5 a-g
Autumn Gold	3.5 e-j	2.2 f	4.5 abc	3.0 abc	-	-	-	3.0 gh	2.8 ghi
BC 8S-26-50	4.0 bcd	3.8 abc	4.3 a-e	4.0 ab	2.8 gh	3.6 cde	3.6 a-d	-	3.4 def
Chinook	3.6 efg	3.3 cde	3.6 h	3.0 b	3.2 ef	3.8 b-e	3.1 c-g	3.7 cde	2.6 hij
Co-op 29 (Sundance™)	4.0 cde	3.5 bcd	4.1 b-e	-	4.1 a	4.1 b	3.7 ab	3.3 efg	3.8 a-d
Co-op 39 (Crimson Crisp™)	4.2 abc	4.5 a	4.4 a-d	4.0 a	4.2 a	-	3.2 c-g	3.8 cde	4.0 a
CQR10T17	3.5 fgh	4.0 abc	4.6 a	4.0 a	4.0 ab	4.7 a	3.4 a-f	4.8 a	3.8 abc
CQR12T50	-[w]	-	-	4.0 a	-	3.5 cde	3.9 a	-	-
Cripp's Pink (Pink Lady®)	-	-	3.7 fgh	4.0 a	3.9 abc	4.0 a-e	-	2.8 h	3.2 efg
Delblush (Tentation®)	3.8 def	4.0 ab	4.1 b-f	4.0 a	3.9 abc	3.8 b-f	3.0 fg	3.4 d-g	2.8 ghi
Golden Delicious (Gibson)	3.0 hij	3.3 b-e	4.0 d-g	3.0 b	2.9 gh	3.6 de	3.1 efg	3.8 cde	2.2 j
Hampshire	3.9 cde	3.7 bc	2.7 i	3.0 b	2.8 gh	3.4 e	2.9 fg	4.0 bc	3.5 a-f
Jubilee Fuji (September Wonder®)	-	-	3.7 fgh	-	2.9 gh	3.4 ef	3.5 a-f	3.6 c-f	3.0 fgh
Minnewashta (Zestar®)	3.4 ghi	4.0 ab	4.1 c-g	3.0 b	2.6 hi	2.6 g	3.6 abc	3.2 fgh	2.8 f-j
McIntosh	-	2.8 def	-	-	-	-	-	-	-
NJ 90	4.4 a	4.0 ab	3.5 h	4.0 a	3.1 efg	3.8 b-e	3.2 a-g	4.0 c	3.6 b-e
NJ 109	3.2 g-j	3.7 bc	-	3.0 b	2.6 hi	2.7 g	2.9 e-h	3.0 gh	3.4 c-f
NY 65707-19	-	3.3 b-e	3.3 h	4.0 a	3.6 cd	4.0 bc	3.2 c-g	4.6 a	-
NY 79507-49	-	2.7 ef	-	-	3.7 bcd	3.4 e	3.5 a-e	3.8 cd	3.4 def
NY 79507-72	3.1 ij	3.8 abc	4.7 ab	4.0 a	4.1 ab	3.4 e	3.2 b-g	3.0 gh	3.1 fg
Pinova	3.0 j	-	3.7 gh	-	3.0 fg	-	2.9 g	-	-
Runkel	3.1 hij	3.3 b-e	3.7 e-h	2.0 c	2.3 i	2.7 g	2.5 h	3.2 fgh	2.5 ij
Silken	4.5 ab	4.5 a	4.7 a-d	3.0 b	4.0 ab	-	3.1 c-g	4.5 ab	4.1 ab

[z] Ratings were based on a 5 point scale where 1 = not crisp, 2 = somewhat crisp, 3 = crisp, 4 = above average crispness, 5 = extremely crisp
[y] Locations: See Table 2 for explanation of location codes
[x] Means within a location not sharing a common following letter are significantly different ($p \leq 0.05$) by pairwise t tests from the analysis of the mixed model
[w] - the cultivar was not planted at this location

Table 3. Generalized least-squares means for sensory juiciness ratings among 23 apple cultivars grown at nine planting locations for the years 2001 through 2004.

Cultivar	Mean juiciness rating[z]								
	MA[y]	NJ	OR	PAB	PAR	UT	VT	WI	WV
Ambrosia	4.2[x] a-e	4.0 abc	3.2 f	4.0 a	3.3 b-e	3.5 cde	3.0 c-f	3.9 ab	3.8 a-i
Autumn Gold	4.1 a-f	3.2 de	3.9 bcd	3.0 abc	-	-	-	3.5 b-e	3.5 bi
BC 8S-26-50	4.2 abc	4.2 ab	4.5 a	4.0 abc	3.5 a-d	4.2 a	3.4 abc	-	3.9 abc
Chinook	3.9 d-g	3.1 de	2.7 gh	4.0 a	3.3 cde	3.2 def	2.9 ef	3.7 bcd	3.0 ijk
Co-op 29 (Sundance™)	2.9 i	3.0 e	4.0 bcd	-	3.5 a-d	3.8 abc	3.5 ab	3.1 e	3.7 a-h
Co-op 39 (Crimson Crisp™)	4.1 b-f	4.3 a	3.7 cde	4.0 a	3.7 a	-	3.3 a-e	2.6 fg	3.8 a-d
CQR10T17	3.9 d-g	3.8 a-e	3.1 fg	3.0 c	3.0 ef	3.1 ef	3.3 a-e	4.0 ab	3.5 c-i
CQR12T50	-[w]	-	-	4.0 a	-	2.8 f	3.7 a	-	-
Cripp's Pink (Pink Lady®)	-	-	2.4 h	4.0 a	3.0 ef	3.2 b-f	-	3.1 ef	3.4 d-j
Delblush (Tentation®)	3.8 efg	3.5 b-e	3.1 fg	4.0 a	3.5 a-d	3.4 cde	2.7 f	3.0 ef	3.6 b-g
Golden Delicious (Gibson)	3.4 gh	4.0 abc	3.7 cd	4.0 a	3.2 c-f	4.0 ab	3.0 def	3.2 de	3.0 j
Hampshire	4.2 a-d	3.8 a-d	3.1 fg	3.0 bc	3.6 ab	4.0 a	3.1 b-e	3.0 efg	4.3 a
Jubilee Fuji (September Wonder®)	-	-	4.7 a	-	3.5 a-d	3.5 b-e	3.4 a-e	3.2 e	3.9 a-f
Minnewashta (Zestar®)	4.0 b-f	3.5 b-e	3.3 ef	4.0 a	3.3 cde	2.2 g	3.4 a-d	3.4 cde	2.3 k
McIntosh	-	3.5 b-e	-	-	-	-	-	-	-
NJ 90	4.5 a	4.0 abc	3.8 cd	4.0 a	3.5 a-d	4.0 ab	3.7 a	3.8 bc	3.9 ab
NJ 109	3.7 fgh	3.3 cde	-	3.6 ab	3.2 c-f	3.1 def	2.8 def	2.6 fg	3.1 hij
NY 65707-19	-	3.0 e	3.8 bcd	4.0 a	3.6 abc	3.8 abc	3.0 def	3.2 e	-
NY 79507-49	-	3.2 de	-	-	3.3 a-e	3.3 def	3.2 a-e	3.4 cde	3.3 g-j
NY 79507-72	3.3 h	3.2 de	3.6 def	3.0 bc	3.1 def	3.6 bcd	3.2 a-e	2.5 g	3.4 e-j
Pinova	3.9 c-g	-	3.3 f	-	3.2 def	-	3.1 a-e	-	-
Runkel	4.0 c-f	3.2 de	4.3 abc	4.0 a	2.9 f	3.5 cde	3.1 b-f	3.9 ab	3.4 d-i
Silken	4.4 ab	4.0 abc	4.6 ab	3.0 bc	3.3 de	-	2.9 ef	4.3 a	3.9 a-e

[z] Ratings were based on a 5 point scale where 1 = dry, 2 = slight juicy, 3 = moderately juicy, 4 = juicy, 5 = extremely juicy

[y] Locations: See Table 2 for explanation of location codes

[x] Means within a location not sharing a common following letter are significantly different ($p \leq 0.05$) by pairwise t tests from the analysis of the mixed model

[w] - the cultivar was not planted at this location

Table 4. Generalized least-squares means for sensory sweetness ratings among 23 apple cultivars grown at nine planting locations for the years 2001 through 2004.

Cultivar	Mean sweetness rating[z]								
	MA[y]	NJ	OR	PAB	PAR	UT	VT	WI	WV
Ambrosia	3.3x a	2.8 cde	4.5 a	4.0 a	3.9 a	3.4 b-e	4.2 a	3.3 bcd	4.3 a
Autumn Gold	2.7 b-e	2.0 f	3.4 cd	3.0 abc	-	-	-	3.7 ab	3.0 c
BC 8S-26-50	3.4 a	2.5 ef	4.6 a	4.0 ab	3.9 a	3.7 a-d	3.5 de	-	4.1 a
Chinook	2.5 cde	3.3 bcd	2.9 de	2.0 cd	3.1 cde	3.9 ab	3.5 cde	3.5 abc	2.4 de
Co-op 29 (Sundance™)	1.2 i	3.0 b-e	2.8 ef	-	2.2 jk	2.6 i	3.2 efg	1.8 h	1.9 ef
Co-op 39 (Crimson Crisp™)	1.6 hi	3.0 b-e	2.9 de	3.0 b	3.0 c-f	-	3.2 efg	2.4 fg	2.5 d
CQR10T17	2.1 fg	2.5 def	2.2 gh	1.0 e	2.0 k	2.6 i	3.4 def	2.0 gh	2.0 ef
CQR12T50	-[w]	-	-	2.0 cd	-	2.8 ghi	3.2 efg	-	-
Cripp's Pink (Pink Lady®)	-	-	2.0 h	2.0 cd	2.5 g-j	2.8 e-i	-	2.8 ef	1.8 f
Delblush (Tentation®)	1.8 gh	2.5 ef	2.4 fgh	2.0 cd	3.1 bcd	3.4 def	3.5 cde	3.9 a	1.6 f
Golden Delicious (Gibson)	2.7 b-e	4.0 a	3.6 bc	3.0 b	3.3 bc	4.0 a	3.8 bcd	4.0 a	3.1 c
Hampshire	2.5 cde	3.2 b-e	2.6 ef	1.3 de	2.7 fgh	3.8 abc	3.3 ef	2.8 def	3.2 bc
Jubilee Fuji (September Wonder®)	-	-	4.3 a	-	3.4 b	2.8 hi	4.0 abc	2.8 ef	3.9 a
Minnewashta (Zestar®)	2.7 bcd	3.1 b-e	3.8 bc	2.0 cd	2.8 d-g	3.0 ghi	3.2 efg	3.1 cde	2.2 def
McIntosh	-	3.0 b-e	-	-	-	-	-	-	-
NJ 90	2.8 bc	3.5 abc	3.9 b	2.0 cd	2.5 g-j	3.3 c-g	3.5 a-f	3.6 ab	2.5 d
NJ 109	1.7 ghi	2.7 def	-	1.0 e	2.4 hij	3.0 f-i	3.6 a-e	2.0 gh	1.6 f
NY 65707-19	-	3.0 b-e	3.0 de	1.0 e	2.3 ijk	3.2 e-h	2.8 g	1.9 gh	-
NY 79507-49	-	2.8 cde	-	-	2.7 fgh	3.5 b-e	4.1 ab	3.8 a	3.1 c
NY 79507-72	2.3 ef	3.2 b-e	2.4 efgh	1.0 e	3.0 b-f	3.5 b-e	2.8 fg	2.8 ef	1.8 f
Pinova	2.3 def	-	3.7 bc	-	2.8 e-h	-	3.5 de	-	-
Runkel	2.9 b	3.7 ab	2.7 efg	2.0 cd	3.1 b-e	3.7 a-d	3.1 efg	3.6 ab	4.1 a
Silken	2.6 b-e	3.5 abc	2.4 efgh	3.0 b	2.6 ghi	-	4.0 ab	3.9 a	3.7 ab

[z] Ratings were based on a 5 point scale where 1 = none detected, 2 = slightly sweet, 3 = moderately sweet, 4 = sweet, 5 = very sweet
[y] Locations: See Table 2 for explanation of location codes
[x] Means within a location not sharing a common following letter are significantly different ($p \leq 0.05$) by pairwise t tests from the analysis of the mixed model
[w] - the cultivar was not planted at this location

Table 5. Generalized least-squares means for sensory acidity ratings among 23 apple cultivars grown at nine planting locations for the years 2001 through 2004.

Cultivar	Mean acidity rating[z]								
	MA[y]	NJ	OR	PAB	PAR	UT	VT	WI	WV
Ambrosia	2.5[x] gh	3.0 bc	2.2 g	1.0 e	2.3 g	1.4 k	1.9 fgh	1.1 j	1.0 fg
Autumn Gold	2.6 fgh	2.3 cd	2.1 g	1.0 de	-	-	-	1.7 i	1.1 g
BC 8S-26-50	2.7 fg	2.3 cd	1.5 h	1.0 de	2.3 g	1.5 jk	2.1 e-h	-	1.1 g
Chinook	2.8 fg	3.0 bc	2.1 g	4.0 a	2.4 g	2.3 e-h	2.2 d-g	1.8 i	1.8 de
Co-op 29 (Sundance™)	3.8 ab	3.0 bc	3.3 cde	-	3.8 ab	3.3 a	2.4 b-e	3.7 cd	3.7 a
Co-op 39 (Crimson Crisp™)	3.9 a	4.0 a	3.6 bcd	3.0 b	3.5 bc	-	2.1 d-h	4.3 ab	2.8 b
CQR10T17	3.6 abc	4.0 a	2.9 e	4.0 a	3.1 de	2.8 bcd	2.7 abc	3.7 bcd	3.0 b
CQR12T50	-[w]	-	-	4.0 a	-	2.4 def	3.0 a	-	-
Cripp's Pink (Pink Lady®)	-	-	4.1 a	4.0 a	3.9 ab	3.4 ab	-	3.9 bcd	4.0 a
Delblush (Tentation®)	3.7 ab	4.0 a	3.7 abc	4.0 a	4.1 a	2.9 abc	2.8 ab	3.1 ef	4.0 a
Golden Delicious (Gibson)	2.9 efg	3.0 bc	3.0 e	2.0 cd	2.9 e	2.4 def	2.1 e-h	3.5 de	2.1 cd
Hampshire	3.2 de	2.8 bc	1.9 gh	4.0 a	2.5 fg	2.4 ef	2.1 d-h	2.7 fg	1.7 def
Jubilee Fuji (September Wonder®)	-	-	1.1 i	-	1.8 h	1.8 h-k	1.6 h	1.8 i	1.4 efg
Minnewashta (Zestar®)	3.5 bcd	3.0 b	3.1 e	4.0 a	3.3 cd	2.6 cde	3.1 a	4.0 bc	2.7 bc
McIntosh	-	3.5 ab	-	-	-	-	-	-	-
NJ 90	3.0 ef	3.0 bc	3.0 e	3.0 b	3.1 de	2.0 f-i	2.1 c-h	2.7 fg	2.8 b
NJ 109	3.7 abc	3.5 ab	-	4.0 a	3.7 b	1.7 ijk	2.9 ab	4.7 a	2.9 b
NY 65707-19	-	2.8 bc	3.1 e	4.0 a	3.2 cde	2.2 efg	2.4 bcd	4.1 bc	-
NY 79507-49	-	1.8 d	-	-	2.5 fg	1.9 g-j	2.1 d-h	2.2 hi	1.8 de
NY 79507-72	3.4 cde	3.0 bc	3.9 ab	3.0 b	2.9 def	2.1 f-i	2.4 b-f	3.8 cd	2.7 b
Pinova	3.3 cde	-	3.0 e	-	3.3 cd	-	2.9 a	-	-
Runkel	2.2 h	2.8 bc	2.2 fg	2.0 c	1.9 h	1.0 l	1.8 gh	1.9 i	1.2 fg
Silken	3.0 ef	3.0 bc	2.9 def	1.0 e	2.4 g	-	0.9 i	2.6 gh	1.3 efg

[z] Ratings were based on a 5 point scale where 1 = none detected (bland), 2 = weakly acidic, 3 = moderately acidic (slightly tart), 4 = acidic (tart), 5 = highly acidic (very tart)
[y] Locations: See Table 2 for explanation of location codes
[x] Means within a location not sharing a common following letter are significantly different ($p \leq 0.05$) by pairwise t tests from the analysis of the mixed model
[w] - the cultivar was not planted at this location

considered tarter than 'Golden Delicious' by most cooperators. Among the scab-resistant cultivars, all the Purdue University selections ('Co-op 29', 'Co-op 39', CQR10T17, CQR12T50) were rated as more acidic than 'Golden Delicious' at most locations, but the New York selections were in many cases less than or similar to 'Golden Delicious' in acidity rating.

In a previous study conducted with protocols similar to this one, the sensory scores for crispness, juiciness and sweetness of 20 cultivars were consistent across seven locations, although acidity ratings were not (10). There is no obvious explanation for the difference, unless it relates to the greater geographic range of locations in the present trial.

Hedonic ratings. 'Golden Delicious' received a flavor rating of at least 3.0 (=acceptable) at all locations (Table 6). Cultivars whose flavor was disliked (score less than 3.0) at a majority of sites included CQR10T17 (all 9 sites) and 'Co-op 29' (5 of 8 sites). NY 79507-72 was below 3.0 at four of nine sites, and was liked less than 'Golden Delicious' at a further four sites. 'Ambrosia' was liked at all sites, including Utah, where only one other cultivar ('Chinook') rated as high in flavor as the standard, 'Golden Delicious'. Other cultivars that rated 3.0 or higher at all sites where they were planted were: CQR12T50, 'Pinova' and 'Minnewashta' (Zestar!®).

The external appearance of the fruit was rated as attractiveness, and included such aspects as color, shape, uniformity and skin finish (russet, lenticels, skin brilliance). Three cultivars received ratings of acceptable (3.0) or higher at all sites: 'Ambrosia', NY 79507-72, and 'Pinova' (Table 7). Among scab-resistant apples, 'Co-op 39', NY 79507-72 and CQR10T17 were rated equal to or more attractive than 'Golden Delicious'. However, the 'Golden Delicious' standard was rated below acceptable at five of nine locations; none of the others rated it higher than 3.2. Other cultivars with low attractiveness ratings at a majority of sites were 'Co-op 29' (all 8 sites) and BC 8S-26-50 (7 of 8 sites). These two cultivars and 'Golden Delicious' all had considerable skin russet (13).

The desirability rating integrated a number of factors contributing to commercial success (texture, flavor, appearance, external or internal problems with the fruit). Despite its low attractiveness scores, 'Golden Delicious' was considered commercially desirable (≥ 3.0) at all 9 sites (Table 8). One wonders whether it would have been considered commercially desirable at some sites were it being newly introduced. Other cultivars that rated at least 3.0 at all reporting locations were CQR12T50 (3 sites), 'Pinova' (4 sites) and 'Ambrosia' (9 sites). 'Minnewashta' (Zestar!®) was considered desirable at eight of the nine sites. Among the scab resistant selections, NY 65707-19 and 'Co-op 39' were rated as desirable the most frequently. In contrast, CQR10T17 was rated below acceptable at eight of nine sites. This low rating may relate to its low scores for sweetness and flavor liking, high score for acidity, and the propensity of this selection to develop severe watercore. The other cultivars differed from location to location without evident patterns.

A weakness of the methodology used in this study is that fruit were tasted by only one person at each location. The extent to which the ratings reflect the personal preferences of that person, as opposed to location effects on quality, cannot be determined. Significant location x cultivar interaction on the ratings for attractiveness, desirability and flavor also occurred in a previous study (10). Hampson and McKenzie (6) conducted formal taste panels for selected sensory attributes, but only used fruit from one location, and no hedonic data were recorded. Ideally, fruit from different locations would be assessed by consumers and/or taste panels, but such testing was beyond the resources of many study participants. The logistics of testing over 20 cultivars, each within 7 days of harvest, would also be formidable.

Data on horticultural performance and objective fruit quality measurements (such as firmness, fruit size, red color) are now

Table 6. Generalized least-squares means for sensory flavor ratings among 23 apple cultivars grown at nine planting locations for the years 2001 through 2004.

Cultivar	Mean flavor rating[z]								
	MA[y]	NJ	OR	PAB	PAR	UT	VT	WI	WV
Ambrosia	4.1x a-d	3.3 b-e	3.3 de	4.0 b	4.0 a	4.1 ab	3.8 c	3.3 b	4.2 ab
Autumn Gold	3.6 c-f	2.7 ef	3.2 ef	3.0 bcd	-	-	-	4.7 a	3.1 ef
BC 8S-26-50	4.2 a	2.3 f	3.1 ef	4.0 abc	3.2 cde	3.8 bcd	3.3 d-g	-	3.5 b-e
Chinook	3.7 de	3.0 c-f	2.8 fg	3.0 c	3.0 def	4.0 abc	3.2 fgh	3.6 b	2.4 g
Co-op 29 (Sundance™)	2.6 h	1.0 g	3.4 cde	-	2.9 d-g	3.2 f	2.9 ghi	2.0 e	3.5 a-f
Co-op 39 (Crimson Crisp™)	3.1 fg	5.0 a	3.8 bc	4.0 b	2.9 d-g	-	3.2 d-g	1.8 e	3.7 abc
CQR10T17	2.6 h	2.8 def	2.5 g	1.0 e	2.2 h	2.7 g	2.5 ij	2.2 e	2.2 g
CQR12T50	-[w]	-	-	4.0 b	-	3.3 def	3.1 e-i	-	-
Cripp's Pink (Pink Lady®)	-	-	3.4 cde	5.0 a	3.4 bc	3.3 b-g	-	2.2 e	3.3 c-f
Delblush (Tentation®)	2.9 gh	4.0 b	3.8 bc	2.0 d	3.4 c	3.8 bcd	4.2 ab	3.3 b	2.9 f
Golden Delicious (Gibson)	3.6 b-f	4.0 b	4.0 b	3.0 c	3.8 ab	4.4 a	4.0 bc	3.4 b	3.2 def
Hampshire	4.0 a-d	3.0 c-f	2.5 g	1.0 e	3.5 bc	3.7 b-e	2.8 hij	3.2 bc	3.9 a-d
Jubilee Fuji (September Wonder®)	-	-	3.3 e	-	3.5 bc	3.0 fg	4.1 abc	2.2 e	4.0 a
Minnewashta (Zestar®)	4.1 abc	4.0 b	4.5 a	4.0 b	3.6 bc	3.3 ef	3.7 bcd	3.3 b	3.3 a-f
McIntosh	-	3.5 bcd	-	-	-	-	-	-	-
NJ 90	4.2 a	3.7 bc	3.7 bcd	3.0 c	2.8 fg	3.7 b-e	3.5 b-g	3.5 b	3.7 abc
NJ 109	3.2 efg	3.7 bc	-	2.0 d	3.3 cd	3.0 fg	3.6 c-f	1.8 e	2.0 gh
NY 65707-19	-	3.0 c-f	3.4 cde	2.0 d	3.0 d-g	3.6 cde	3.7 c	2.8 cd	-
NY 79507-49	-	2.3 f	-	-	2.9 d-g	3.7 b-e	3.8 bc	3.3 b	3.7 abc
NY 79507-72	3.5 ef	3.2 cde	3.2 def	2.0 d	2.5 gh	3.3 ef	3.0 f-i	2.4 de	1.6 h
Pinova	3.5 ef	-	4.1 ab	-	3.0 def	-	4.3 a	-	-
Runkel	3.3 fg	3.5 bcd	2.4 g	1.0 e	2.3 h	3.4 def	2.4 j	3.6 b	3.8 ab
Silken	4.2 ab	4.0 b	3.5 b-f	3.0 c	2.9 efg	-	3.7 cde	4.4 a	3.5 a-f

[z] Ratings were based on a 5 point scale where 1 = dislike (poor), 2 = dislike slightly (fair), 3 = like (acceptable), 4 = good (above average), 5 = like very much
[y] Locations: See Table 2 for explanation of location codes
[x] Means within a location not sharing a common following letter are significantly different ($p \leq 0.05$) by pairwise t tests from the analysis of the mixed model
[w] - the cultivar was not planted at this location

Table 7. Generalized least-squares means for attractiveness ratings among 23 apple cultivars grown at nine planting locations for the years 2001 through 2004.

Cultivar	Mean attractiveness rating[z]								
	MA[y]	NJ	OR	PAB	PAR	UT	VT	WI	WV
Ambrosia	4.2x abc	4.0 ab	4.2 a	4.0 a	3.9 ab	3.1 ab	4.6 a	4.4 ab	3.8 a-e
Autumn Gold	3.3 ef	3.0 cde	4.0 a	2.0 b-e	-	-	-	2.5 ij	3.1 efg
BC 8S-26-50	2.5 g	2.6 de	3.0 cde	1.0 e	1.3 i	1.8 f	2.8 ghi	-	1.4 k
Chinook	3.8 b-e	2.6 e	3.8 a	3.0 b	2.4 h	3.2 ab	3.4 def	3.9 cd	2.4 hi
Co-op 29 (Sundance™)	2.1 g	1.0 f	2.6 e	-	2.5 gh	2.7 bcd	2.5 i	2.4 j	1.7 jk
Co-op 39 (Crimson Crisp™)	3.8 cde	4.5 a	4.0 a	2.8 bc	2.6 fgh	-	3.4 def	3.4 d-h	4.5 a
CQR10T17	2.5 g	3.2 b-e	2.5 e	2.4 bcd	2.9 fg	2.9 a-d	3.8 bcd	4.0 bcd	3.9 bc
CQR12T50	-[w]	-	-	2.0 cde	-	1.8 f	3.4 b-f	-	-
Cripp's Pink (Pink Lady®)	-	-	2.9 cde	4.0 a	4.1 a	3.4 ab	-	4.3 abc	4.5 ab
Delblush (Tentation®)	3.2 f	4.1 ab	3.3 bc	2.5 bcd	3.0 ef	2.6 d	3.5 cde	3.2 fgh	1.6 k
Golden Delicious (Gibson)	2.0 g	3.2 b-e	3.0 cde	3.0 b	2.9 fg	3.1 ab	2.8 hi	1.8 j	2.4 hi
Hampshire	4.2 abc	3.6 abc	2.8 de	3.0 b	4.0 a	3.2 a	3.2 efg	3.8 c-f	3.8 a-e
Jubilee Fuji (September Wonder®)	-	-	3.2 cd	-	3.4 cd	2.7 a-d	3.2 d-h	2.9 hi	3.3 def
Minnewashta (Zestar®)	3.3 f	4.0 ab	3.9 a	3.0 b	3.3 de	2.1 ef	3.6 b-f	3.6 d-g	2.0 ijk
McIntosh	-	3.0 cde	-	-	-	-	-	-	-
NJ 90	4.5 a	3.8 ab	4.1 a	3.0 b	3.9 a	2.7 b-e	3.7 b-f	3.3 e-h	4.5 a
NJ 109	3.6 def	3.3 b-e	-	3.0 b	2.8 fgh	2.5 cde	3.7 b-f	3.0 ghi	2.4 g-j
NY 65707-19	-	3.5 bcd	4.0 a	4.0 a	3.7 abc	2.8 a-d	4.0 b	4.8 a	-
NY 79507-49	-	1.5 f	-	-	3.9 a	3.0 abc	3.6 b-f	4.0 bcd	2.9 fgh
NY 79507-72	4.0 bcd	3.5 bcd	3.1 cde	3.0 b	4.1 a	3.0 abc	4.8 a	4.0 bcd	3.8 cd
Pinova	3.3 f	-	4.0 a	-	3.5 bcd	-	3.9 bc	-	-
Runkel	3.3 f	3.3 b-e	4.3 a	2.0 de	2.6 gh	2.4 de	3.2 e-h	3.1 hi	3.9 c
Silken	4.3 ab	3.8 abc	4.1 ab	3.0 b	2.9 fg	-	3.1 fgh	3.7 de	2.8 f-i

[z] Ratings were based on a 5 point scale where 1 = dislike (ugly), 2 = dislike slightly (fair), 3 = like (acceptable), 4 = good (above average), 5 = like very much
[y] Locations: See Table 2 for explanation of location codes
[x] Means within a location not sharing a common following letter are significantly different ($p \leq 0.05$) by pairwise t tests from the analysis of the mixed model
[w] - the cultivar was not planted at this location

Table 8. Generalized least-squares means for overall desirability ratings among 23 apple cultivars grown at nine planting locations for the years 2001 through 2004.

Cultivar	Mean overall desirability rating[z]								
	MA[y]	NJ	OR	PAB	PAR	UT	VT	WI	WV
Ambrosia	4.2[x] a	3.4 bc	3.5 bc	4.0 b	3.9 a	3.8 a	4.0 b	3.8 cd	4.0 abc
Autumn Gold	3.3 cd	2.5 de	3.2 c-f	3.0 bcd	-	-	-	4.6 a	3.0 e
BC 8S-26-50	3.9 ab	2.5 de	3.2 cde	1.0 ef	2.0 k	3.0 def	2.8 fg	-	1.8 gh
Chinook	3.6 bc	2.6 de	2.8 efg	3.0 c	2.2 ijk	3.5 a-d	2.9 fg	3.4 def	1.4 h
Co-op 29 (Sundance™)	2.5 f	1.0 f	3.4 bcd	-	2.7 gh	3.3 b-e	2.2 h	2.4 ij	2.3 fg
Co-op 39 (Crimson Crisp™)	3.1 de	4.5 a	4.0 a	4.0 b	2.5 hi	-	3.3 de	2.1 j	3.4 cde
CQR10T17	2.5 f	3.3 bcd	2.0 h	1.0 f	2.1 jk	2.7 f	2.4 gh	2.1 ij	2.2 g
CQR12T50	-[w]	-	-	4.0 b	-	3.2 b-f	3.1 def	-	-
Cripp's Pink (Pink Lady®)	-	-	2.7 fg	5.0 a	3.8 ab	3.2 a-f	-	2.1 j	3.5 cde
Delblush (Tentation®)	2.7 ef	4.0 ab	3.4 bcd	2.0 de	3.1 efg	3.6 ab	3.9 b	2.9 gh	2.2 g
Golden Delicious (Gibson)	3.3 cd	4.0 ab	4.0 a	3.0 c	3.5 bcd	3.8 a	3.8 b	3.1 efg	3.1 de
Hampshire	4.0 a	3.5 bc	2.5 g	1.0 f	3.6 ab	3.5 ab	2.9 ef	3.1 efg	4.2 ab
Jubilee Fuji (September Wonder®)	-	-	3.3 cd	-	3.7 ab	2.9 ef	4.0 ab	2.3 ij	4.1 a
Minnewashta (Zestar®)	3.9 ab	4.0 ab	4.0 a	4.0 b	3.5 abc	2.7 f	3.9 b	3.0 fg	3.0 c-f
McIntosh	-	3.5 bc	-	-	-	-	-	-	-
NJ 90	4.0 a	4.0 ab	3.7 ab	3.0 c	2.9 efg	3.3 a-e	3.1 c-g	3.6 cde	3.5 bcd
NJ 109	3.1 de	3.4 bc	-	2.0 de	2.7 fgh	2.9 ef	2.0 h	2.1 j	2.1 g
NY 65707-19	-	3.5 bc	3.4 bcd	3.0 c	3.1 def	3.5 abc	3.9 b	2.7 ghi	-
NY 79507-49	-	2.0 e	-	-	3.2 cde	3.4 a-d	3.6 bcd	3.9 bc	3.6 bcd
NY 79507-72	3.4 cd	3.0 cd	2.9 d-g	2.0 de	2.8 e-h	3.3 b-e	3.1 def	2.5 hij	2.0 g
Pinova	3.4 cd	-	3.5 bcd	-	3.1 def	-	4.5 a	-	-
Runkel	3.1 d	3.5 bc	2.4 gh	2.0 de	2.4 hij	3.1 cde	2.3 h	3.4 def	3.2 de
Silken	4.3 a	4.0 ab	3.4 a-f	3.0 c	2.9 efg	-	3.8 bc	4.3 ab	2.9 ef

[z] Ratings were based on a 5 point scale where 1 = dislike (poor), 2 = fair, 3 = acceptable, 4 = good, 5 = excellent
[y] Locations: See Table 2 for explanation of location codes
[x] Means within a location not sharing a common following letter are significantly different ($p \leq 0.05$) by pairwise t tests from the analysis of the mixed model
[w] - the cultivar was not planted at this location

available for the cultivars in this trial (4,13). The number of cultivars worthy of consumer testing can probably be reduced substantially after eliminating those with unacceptable horticultural performance. The cultivars should also be tasted again after a period of cold storage, because some cultivars have not reached their optimal eating quality at the time of harvest (e.g. 'Chinook', 'Cripp's Pink', 'Co-op 29'). The next step could be to do consumer testing on cultivars that do well in a majority of locations, as well as those that do particularly well in specific sites.

The results of the present trial support those of previous authors, in that no location produced the best sensory quality in all cultivars, and conversely, no cultivar had the best sensory quality at all locations (11). Systematic evaluation to ascertain performance in a variety of climatic and edaphic conditions is recommended, followed by consumer preference testing on the best-performing genotypes.

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