

Performance of Apple Cultivars in the 1995 NE-183 Regional Project Planting: III. Fruit Sensory Characteristics

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Abstract

Appearance and internal sensory quality are important aspects to cultivar adaptation because they influence consumers' decisions in purchasing apples (*Malus x domestica* Borkh.) for fresh consumption. Our objective was to examine the sensory quality of twenty test cultivars grown at various locations in the eastern United States and in Summerland, British Columbia, Canada. From 1998 to 2000, fruit quality at harvest was assessed for attractiveness, desirability, flavor, crispness, juiciness, sweetness and acidity using defined rating scales. In Summerland, fruit quality was assessed after a period of air storage at 1 °C relative to commercial cultivars of similar harvest period, using slightly different rating scales. Cultivars differed in crispness, juiciness and sweetness, but ratings were generally consistent across locations. 'Creston', 'GoldRush', 'Honeycrisp', 'Braeburn' and 'Ginger Gold' rated high for crispness and 'Enterprise', 'Pristine' and NY 75414-1 rated low. 'Honeycrisp', 'Creston', 'Golden Supreme' and 'Shizuka' were rated highest for juiciness. 'Fuji' and 'Orin' rated highest and 'GoldRush' and 'Pristine' rated lowest for sweetness, whereas the opposite was true for acidity ratings. Other sensory attributes were affected by the interaction between location and cultivar. No single cultivar was superior at all sites. Some site-to-site differences in fruit attractiveness appeared to arise from climatic influences on skin finish or color development. Results support the need for widespread systematic testing of new apple cultivars.

Introduction

Appearance has long been associated with the U. S. consumer's buying habits when purchasing apples. While characteristics such as color, size, and finish continue to be important factors (18), recent surveys and taste panels indicate that many consumers are selecting apples based on taste, flavor, and other internal quality attributes (20, 25, 28). When asked why they buy apples, about 70% of U.S. consumers indicated that eating quality (flavor, taste, texture) was the reason for their purchase (19). Consumer surveys in other countries provide similar findings indicating internal quality (flavor, taste, crispness, etc.) ranks above appearance in importance among apple characteristics (25, 27). Harker (19) indicates that a one percent decrease in apple price will increase sales by only about one percent, but a one percent increase in quality could improve demand for apples by 12 to 59 percent, further evidence of the importance of internal quality in consumer purchasing of apples.

Health is also an important factor in the consumer's choice of apples over other food products (20). The old adage "an apple a day keeps the doctor away" has long been heralded by parents and educators as a reason for eating apples. Recent research results clearly demonstrate the health and dietary benefits of eating apples (6, 12, 26, 32). However, a study in England found that consumers are reluctant to repurchase fruits that do not taste good, no matter how healthy they may be (20).

In addition to internal quality, today's consumers are looking for a choice in taste and flavor when they purchase apples (1, 25). Traditional apple cultivars, such as 'Delicious' and 'Golden Delicious', present a very limited range in internal quality. When presented to taste panels, newer apple cultivars such as 'Fuji', 'Braeburn', 'Gala', 'Pink Lady' or 'Honeycrisp' have consistently received higher preference ratings than 'Delicious' and 'Golden Delicious' (10, 25, 30). Knowledge of apple quality characteristics most demanded by consumers can assist breeders in selecting

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new cultivars (17) and would aid growers in deciding which cultivars to plant.

In the past, most new apple cultivars have been introduced based on local evaluation by the breeder(s) and/or limited observations by nursery personnel or growers. The need for a detailed, systematic evaluation of new apple cultivars has been recognized (22). In 1994 the USDA Cooperative State Research, Education, and Extension Service Regional Project NE-183 titled "Multidisciplinary Evaluation of New Apple Cultivars" was initiated to systematically evaluate the performance of new apple cultivars in replicated trials under a wide range of climatic and edaphic conditions. Description and background information on the NE-183 Regional Project is provided by Greene et al. (15). Our objective is to report the results of the 1995 NE-183 trial on the sensory quality of 20 cultivars grown at various locations in the eastern United States and in Summerland, British Columbia, Canada.

Materials and Methods

Trees of 23 apple cultivars were propagated on Malling 9 (M.9) T337 rootstock by Adams County Nursery (Aspers, PA, USA) in 1993 (Table 1). 'Golden Delicious' was included in this evaluation to provide a standard commercial reference cultivar. The 1-year-old trees were dug in the fall of 1994 and planted at 28 sites in the United States and Canada in spring 1995. Two cultivars, 'Senshu' and 'Pioneer Mac', were planted only at sites designated for the "disease objective study" and will not be discussed in this paper (not included in Table 1). The cultivar 'Sansa' was also deleted from the study due to a virus infection detected in the scion of all budded trees after planting (not listed in Table 1). Cooperators at 7 locations (Table 2), representing 8 planting sites (the West Virginia location provided sensory data from a "horticultural" planting and a "disease" planting), provided fruit sensory data for the years 1998 through 2000. The experimental design was a randomized complete block with five blocks and a single tree of each cultivar per block. Because of a tree shortage among cultivars, some plantings were unbalanced with fewer than five replications. Filler trees, selected by the local cooperator, were used

to maintain the original experimental design where necessary. Trees were planted in north-south rows, when possible, at a spacing of 2.5 x 4.3 m. Details regarding the planting and cultural maintenance of the NE-183 plantings are presented by Crassweller et al. (7).

Protocol for eastern U.S. planting sites. While some cultivars set fruit in 1996 and 1997, any fruit data collected for those years are not included in this paper. A standard protocol was developed for collecting fruit sensory ratings data. In 1998 and thereafter cooperators were instructed to harvest each cultivar when the average starch index [SI (rated on a 1 to 8 scale)] rating fell within the range of 4 to 6 (considered optimum maturity for fresh consumption) based on the Cornell Generic Starch-Iodine Index Chart (3). Data were collected on an individual tree basis when possible. Five apples were selected from each replicate tree that were representative of the cultivar in size, appearance, and maturity as described above. If less than five apples were available from a single tree, a composite sample of five fruits was selected from several trees of the given cultivar. Fruit were brought to room temperature (21 to 25°C) for analysis. If fruit could not be brought to room temperature and analyzed the day of collection, cooperators were instructed to store fruit in regular cold storage (1 to 5°C) until analysis could be performed. Sensory analysis was performed within seven days of fruit harvest by a single taster.

Seven attributes were identified as common factors for rating by all cooperators: attractiveness, desirability, flavor, crispness, juiciness, acidity, and sweetness. A definition of each attribute is given in Table 3. A bipolar 5-point (1 to 5) hedonic scale was used to rate cultivars for attractiveness, desirability, and flavor. On the scale the 1-unit intervals were considered: dislike, dislike slightly, like, like very much, and like extremely. To adequately assess attractiveness, cooperators were instructed to lightly polish the surface of the fruit with a soft towel to remove dust, spray deposit, bloom, or other surface residues.

A 1 to 5 unipolar intensity scale was used to rate textural (crispness and juiciness) and flavor (sweetness and acidity) attributes as follows: crispness: 1 = not crisp, 2 = somewhat crisp, 3 = crisp, 4 = above average crispness,

Table 1. Apple cultivars and selections evaluated for selected sensory characteristics in the 1995 NE-183 “Multidisciplinary Evaluation of New Apple Cultivars” Regional Project².

Cultivar	Cultivar
Arlet (Swiss Gourmet)	Golden Supreme
Braeburn	GoldRush (originally Co-op 38)
Cameo (originally Carousel)	Honeycrisp
Creston (originally BC8M15-10)	NY75414-1
Enterprise (originally Co-op 30)	Orin
Fortune (originally NY 429)	Pristine (originally Co-op 32)
Fuji Red Sport #2	Shizuka
Gala Supreme	Suncrisp (originally NJ 55)
Ginger Gold	Sunrise
Golden Delicious, Gibson strain	Yataka Fuji

²Photographs of apple cultivars are available on NE-183 web site: www.183.org/cultivars/cultivars.html

Table 2. Locations and cooperators in the 1995 multidisciplinary apple cultivar evaluation trial coordinated by NE-183 who submitted fruit sensory rating data.

(BC)	British Columbia	Cheryl R. Hampson	Summerland, Canada
(MA)	Massachusetts	Duane W. Greene, Jon Clements	Belchertown
(NYG)	New York	Susan K. Brown	Geneva
(PAB)	Pennsylvania	George M. Greene II	Biglerville
(PAR)	Pennsylvania	Robert M. Crassweller	Rock Springs
(VT)	Vermont	M. Elena Garcia, Lorraine P. Berkett	Burlington
(WV)	West Virginia	Stephen S. Miller	Kearneysville
(WVD)	West Virginia, disease	Stephen S. Miller	Kearneysville

and 5 = extremely crisp; juiciness: 1 = dry, 2 = slightly juicy, 3 = moderately juicy, 4 = juicy, and 5 = extremely juicy; sweetness: 1 = none detected, 2 = slightly sweet, 3 = moderately sweet, 4 = sweet, and 5 = very sweet; and acidity: 1 = none detected (bland), 2 = weakly acidic, 3 = moderately acidic (slightly tart), 4 = acidic (tart), and 5 = highly acidic (very tart).

The statistical analysis for comparing cultivars for each sensory attribute was accomplished using a mixed linear statistical

model. The fixed effects in the model were the main effects and interaction effects of cultivar and location. The random effects were the main effects of year and the interaction effects with cultivar and location, the effects of block nested in location, and the effects of tree nested within cultivar, block and location. Generalized least squares means for cultivars were compared within each location if the p-value of the F test for the cultivar-location interaction was less than 0.01. If the p value was larger than 0.01, the model was refit after

Table 3. Definition of sensory attributes used to evaluate apple cultivars in the 1995 NE-183 Multidisciplinary Apple Cultivar Evaluation Regional Project planting.

Attribute	Definition
Attractiveness	► how attractive is the outward appearance of the apple considering background and over-color, shape, uniformity, and finish (russet, lenticels, etc.)
Flavor	► general taste to include aroma, balance of sweet and acid taste, and any immature or over-ripe taste
Desirability	► considering all factors, how do you like this apple; would consumers buy this apple? Would this apple be acceptable to commercial growers in your area's production/marketing system?
Crispness	► how crisp is the flesh of this apple during chewing – firm but brittle producing a distinct crunching sound
Juiciness	► the relative amount of juice released when the flesh is compressed by chewing
Sweetness	► the degree of sweet taste experienced during chewing
Acidity	► the degree of tart (acidity) taste experienced during chewing

removing the interaction effects for location and cultivar and the generalized least squares means for cultivars were compared. In either case, pairwise comparisons were made using a *t* test and significance was declared when the *p* value was smaller than 0.05. The statistical analysis was performed with the MIXED procedure of the SAS statistical software (Release 8.2, SAS Institute Inc., Cary, NC). The "satterth" option was used for determining degrees of freedom and the estimated variance components for the random effects were the "REML" estimates. The generalized least squares means and their pairwise comparisons with no adjustment for multiple testing were obtained using the LSMEANS statement.

Protocol for BC planting site. The BC site regularly conducts sensory evaluations as part of the apple breeding program using taste panels to assess sensory attributes. The standard protocol developed by the NE-183 Project for sensory evaluation was therefore

not used for the apples harvested at the BC site and a modified procedure was employed. Fruit were harvested according to starch index as described above and stored in plastic 19 kg containers in regular air at 1 °C. Storage containers were not fitted with box liners and fruit was exposed to the storage atmosphere. After an indeterminate period of storage, fruit of the NE-183 cultivars were tested alongside apple selections from the breeding program of similar harvest date, using the routine sensory procedures developed and described earlier (17). Thus the NE-183 cultivars at this location were not evaluated at harvest or necessarily by the same taste panel members. Fruit were always warmed to room temperature (20 °C) overnight prior to taste tests. All samples were labeled with random three digit codes. Panels usually considered 10 selections, two of which were commercial cultivars of similar harvest season (internal controls); only data from these internal standards and the NE-183 cultivars

are presented here (the others were unnamed breeding selections). Twelve judges, drawn from a larger pool for each panel, were used to rate the apples.

Appearance, texture and flavor liking were assessed on a 0 (low) to 9 (high) bipolar scale. On the scale, one-unit intervals starting from 0 to 1 were respectively dislike extremely, dislike very much, dislike moderately, dislike slightly, neither like nor dislike, like slightly, like moderately, like very much, like extremely. Appearance liking was rated on five whole apples, but texture and flavor liking were rated on sample apple wedges. The intensity or degree of the attributes skin toughness, crispness, hardness, juiciness, aromatics, sweetness and sourness was rated on unipolar 0 to 9 scales by 12 specially trained judges drawn from another pool. On this scale, 0=not detected, 1=just barely detectable, 3=slight, 5=moderate, 7=intense and 9=extremely intense. Hedonic and attribute-intensity panels were run separately. For both hedonic and attribute-intensity panels, sample order was randomized among judges to eliminate any position bias.

The results of each panel were analyzed as a randomized complete block design with judges as blocks and apple cultivars as treatments. To combine results over several years, means and the differences between means were weighted inversely to the error mean square for each panel, i.e. $\text{weight} = (1/[2 \times \text{error mean square/df}])$. The significance of the weighted difference between means was then assessed by hand calculation of the t-test statistic ($p = 0.05$), taking as the degrees of freedom the lowest number of error degrees of freedom from the panels used in the weighting.

Results and Discussion

Mean starch index (SI) rating at the time of harvest and the mean number of days deviation from the mean harvest date for 'Golden Delicious' for the cultivars in this study has been reported (24). Based on the target acceptable SI range (3.5 to 6.5), 'Yataka Fuji' (mean SI 7.4) was judged over mature at all sites except the BC site. 'Yataka Fuji' was therefore deleted from the statistical analysis and data reported for the seven eastern U.S. sites since fruit at this SI level was not considered representative of the

cultivar. However, data will be reported from the BC site for 'Yataka Fuji' where fruit were harvested within the acceptable SI range (SI 5.8).

Eastern U.S. planting sites. The two-way interaction for cultivar and location was not significant for crispness, juiciness, or sweetness. Location affected crispness and sweetness rating, but not juiciness (Table 4). Except at the NYG site, apple cultivars from the more northern planting sites (VT, MA, and PAR) were rated crisper than apples harvested from the more southern sites (PAB, WV, and WVD). Apple cultivars at the VT site rated significantly sweeter than all other sites while cultivars rated significantly lower in sweetness at the MA, PAB, WV, and WVD planting sites. It is interesting to note that mean soluble solids concentration (SSC) was lowest for the VT location among 14 sites reporting this variable (data not shown). This suggests that differences in perceived sweetness may be related as much, or more, to the taster and to sweetness and/or acidity of the cultivars that predominate within a region (e.g., 'McIntosh' in New England versus 'Delicious' and 'Golden Delicious' in the Mid-Atlantic) rather than to true cultivar differences. However mean SSC was among the lowest reported for the PAB, WV, and MA among 14 sites (data not shown) and these sites did report a significantly lower sweetness sensory rating (Table 4)

Among the 19 cultivars evaluated, 'Creston' and 'GoldRush' rated higher in flesh crispness than all other cultivars except 'Honeycrisp', 'Braeburn', and 'Ginger Gold' (Table 4). 'Creston' was rated fully above average in crispness while 'GoldRush', 'Honeycrisp', 'Braeburn', and 'Ginger Gold' rated between crisp and above average crispness. It is somewhat surprising that 'Honeycrisp' did not rate higher for crispness since it has been widely advertized as having exceptional or "explosive" crispness (2, 14). 'Enterprise', a scab-resistant cultivar that resembles 'Rome Beauty', was rated lowest for flesh crispness. 'Pristine' and the selection NY75414-1 also rated less than fully crisp at harvest. 'Pristine' is a very early maturing cultivar [about 58 days before 'Golden Delicious' (24)] with short shelf life which may explain the low crispness rating. NY 75414-1, a scab-resistant cross of

Table 4. Generalized least-squares means for cultivar main effects on sensory rating scores for crispness, juiciness and sweetness, for 19 apple cultivars evaluated over 7 planting sites in the eastern United States in the 1995 NE-183 Multidisciplinary Apple Cultivar Evaluation Regional Project for the years 1998 through 2000.

Main effect	Mean sensory scores based on a unipolar 1 to 5 intensity scale ^z		
	Crispness	Juiciness	Sweetness
Location			
MA	3.7 a ^y	3.9 a	2.2 d
NYG	3.1 b	3.7 a	3.1 b
PAB	3.0 b	3.4 a	2.2 d
PAR	3.7 a	3.7 a	2.8 bc
VT	3.6 a	3.6 a	3.5 a
WV	3.0 b	3.6 a	2.4 cd
WVD	3.1 b	3.6 a	2.4 d
Cultivar/selection			
Arlet	3.1 fgh	3.5 def	2.5 ef
Braeburn	3.7 abc	3.8 bcd	2.2 fg
Cameo	3.5 bcde	3.7 cde	2.5 ef
Creston	4.0 a	4.2 ab	2.5 efg
Enterprise	2.7 i	3.3 f	2.4 efg
Fortune	3.2 def	3.4 ef	2.4 efg
Fuji Red Sport #2	3.2 defg	3.9 abc	3.6 ab
Gala Supreme	3.3 def	3.3 f	2.7 de
Ginger Gold	3.8 abcd	3.9 abcde	2.8 cde
Golden Delicious	3.0 fgh	3.3 f	2.9 cd
Golden Supreme	3.4 cdef	4.0 ab	3.2 c
GoldRush	3.9 a	3.6 cdef	1.8 h
Honeycrisp	3.8 ab	4.2 a	2.6 def
NY 75414-1	2.8 ghi	3.6 cdef	2.3 efg
Orin	3.1 fgh	3.6 cdef	3.9 a
Pristine	2.8 hi	3.3 f	2.0 gh
Shizuka	3.2 defg	4.0 abc	3.2 bc
Suncrisp	3.2 efg	3.4 ef	2.4 efg
Sunrise	3.3 def	3.3 f	2.5 ef

^z Rating based on unipolar intensity scale where 1 = least and 5 = most; see text for details.

^y Means for the same attribute and main effect category not sharing a common following letter are significantly ($P \leq 0.05$) different by pairwise t tests from the analysis of the mixed model for the attribute.

'Liberty' x 'MacSpur', has been reported to have low flesh firmness at harvest (13, 24). However NY75414-1 is described as crisp and juicy among McIntosh type cultivars (5; Susan Brown, personal observation).

'Honeycrisp' and 'Creston' were rated highest for juiciness followed closely by 'Golden Supreme' and 'Shizuka' that were also rated fully juicy (Table 4). 'Fuji Red Sport No. 2' (hereafter referred to as 'Fuji') and 'Ginger Gold' were rated slightly less than fully juicy (4.0), but were not significantly different from 'Honeycrisp' or 'Creston'. All cultivars in this study rated at least moderately juicy at harvest (Table 4).

'Fuji' and 'Orin' received the highest ratings for sweetness while 'GoldRush' and 'Pristine' were rated lowest for sweetness among the 19 cultivars (Table 4). 'Fuji' and 'Orin', selections from Japan, where a premium is placed on sweet flavor, have been characterized as sweet cultivars (16). In our study 'Fuji' and 'Orin' were rated between moderately sweet and sweet, and SSC at harvest was reported as 14.4% and 14.2%, respectively (24). Titratable acidity (TA) for 'Fuji' and 'Orin' was reported as 0.44% and 0.39% (as malic acid), respectively (24) producing an average SSC:TA ratio of 35:1. Given these data, a sensory rating of "sweet" is easily explained. In contrast, Miller et al. (24) reported a mean SSC at harvest for 'GoldRush' of 15.5% and a TA of 0.98% malic acid while 'Pristine' SSC was reported at 12.3% and TA of 0.87% malic acid. Thus the mean SSC:TA ratio for 'GoldRush' and 'Pristine' was only 15:1, which might justify a more acid taste rating. 'GoldRush' is described as "sprightly acid" at harvest (9) and 'Pristine' as a combination of mild acidity and sweetness (21). The sensory ratings in our study represent a wider growing area than might have been used by the breeders, but our findings would tend to support the breeders' descriptions.

There was a significant cultivar x site interaction for the response variables attractiveness, desirability, flavor, and acidity (Tables 5, 6, 7, and 8). No one cultivar received the highest rating for attractiveness from a majority of the sites (Table 5). The results suggest that attractiveness can be attributed to no one common factor, such as

skin color, shape, or finish. This may be an indication of the highly subjective nature of this attribute. 'Golden Supreme' received the highest rating at two sites (MA and WVD), and was not significantly different from the highest rated cultivar at the other five test sites. At the PAB and WV site 'Sunrise' received the highest rating for attractiveness; at the WV site 'Enterprise' was rated the same as 'Sunrise'. At the NYG site seven cultivars were rated 3.0 ("like") for attractiveness, which was the highest mean score assigned at this planting site for this attribute. Likewise, there was no single cultivar rated least attractive among the 19 cultivars at the seven sites. 'Arlet', which is prone to russet (4, 13, 24) was rated least attractive at the VT and NYG sites and among the least attractive at the PAB site. The attractiveness of NY 75414-1 was rated as "dislike" at two sites (PAB and WV), but was rated "like very much" at three sites (VT, MA, and PAR). Interestingly it did not receive a very high rating for attractiveness at the New York site (NYG) where it originated (Table 5). At the WV and WVD sites 'Gala Supreme' and 'Orin' were rated low on attractiveness, primarily because of surface russet and large rough lenticels – both conditions that are common to the high humidity environment of the region.

Project cooperators were instructed to consider all factors (Table 3) including culture, marketing, and potential consumer acceptance when rating cultivars for desirability (Table 6). 'Fortune' was rated between like very much (score 4.0) and like extremely (score 5.0) at VT; 'Honeycrisp', NY75414-1, 'Golden Supreme' and 'Ginger Gold' received similar, but slightly lower ratings (Table 6). At the MA site 'Ginger Gold' and 'Golden Supreme' were most desirable followed closely by 'Shizuka', 'Honeycrisp', 'Creston', 'Cameo', and 'Fuji', which also received ratings of 4.0 or above. 'Honeycrisp' was the only cultivar rated as like very much at the NYG site. It has been suggested that 'Honeycrisp' is best suited for cooler more northern growing regions (2). Data from this study, albeit somewhat limited geographically, would tend to support this suggestion; however, 'Honeycrisp' was rated slightly above a fully "like" (score 3.0) rating at the WV and WVD sites, the most southern planting sites in this data set (Table

Table 5. Generalized least-squares means sensory rating scores for attractiveness among 19 apple cultivars grown at seven planting sites in the eastern United States in the 1995 NE-183 Multidisciplinary Apple Cultivar Evaluation Regional Project for the years 1998 through 2000.

Cultivar/selection	Mean attractiveness rating score ^z						
	Burlington VT	Belchertown MA	Geneva NYG	Rock Springs PAR	Biglerville PAB	Kearneysville WV	Kearneysville WVD
Arlet	1.6 g ^y	3.1 cdef	1.0 c	3.1 abcd	1.3 gh	3.1 ab	2.6 bcde
Braeburn	2.6 cdeg	2.9 def	3.0 a	3.0 abcd	2.5 cdef	3.7 a	3.6 ab
Cameo	2.7 cde	3.7 bcde	3.0 a	3.0 abcd	1.6 gh	2.6 bc	3.0 bcd
Creston	n.d. ^x	2.3 f	2.0 abc	3.2 abcd	1.4 gh	n.d.	1.5 f
Enterprise	2.9 abcdeg	3.5 bcde	3.0 a	4.0 a	3.4 abc	3.9 a	3.4 abc
Fortune	4.2 a	3.8 abc	3.0 ab	3.6 abc	1.9 efgh	n.d.	n.d.
Fuji Red Sport No. 2	n.d.	3.1 cdef	n.d.	4.0 ab	2.3 cdefgh	2.2 bcd	2.9 abcd
Gala Supreme	1.9 efg	2.7 ef	2.5 ab	2.2 d	2.7 cde	1.7 cd	1.6 ef
Ginger Gold	3.2 abcde	3.6 abcdef	3.0 ab	4.0 ab	3.2 bcd	n.d.	n.d.
Golden Delicious	2.8 bcdeg	2.8 ef	2.7 ab	3.5 abc	2.8 cde	2.4 bc	3.5abcd
Golden Supreme	3.7 ab	4.8 a	2.0 abc	3.8 abc	3.8 ab	3.8 a	3.8 a
GoldRush	2.3 deg	2.4 f	2.7 ab	3.0 abcd	1.7 fgh	2.0 bcd	2.4 cdef
Honeycrisp	3.1 bcdf	3.2 cdef	2.0 abc	2.0 d	2.0 efgh	2.7 abc	3.0 abcd
NY 75414-1	4.0 ab	4.0 abc	2.3 ab	4.1 a	1.1 h	1.3 d	n.d.
Orin	2.0 eg	2.4 f	2.0 abc	2.6 cd	1.6 fgh	1.6 cd	1.6 ef
Pristine	3.6 abcd	4.7 ab	1.5 bc	2.7 bcd	3.2 abcd	2.5 bc	2.5 cdef
Shizuka	3.8 abcd	3.0 cdef	3.0 a	4.0 a	1.9 defg	n.d.	2.3 def
Suncrisp	4.0 abc	3.4 bcde	2.7 ab	3.2 abcd	2.0 efgh	3.4 ab	2.6 bcdef
Sunrise	3.8 abcd	3.9 abcd	3.0 a	3.8 a	4.3 a	3.9 a	2.5 abcdef
Avg.	3.1	3.3	2.5	3.3	2.4	2.7	2.7

^z Attribute ratings based on a bipolar hedonic scale where 1 = dislike, 2 = dislike slightly, 3 = like, 4 = like very much, and 5 = like extremely

^y Means for the same location not sharing a common following letter are significantly ($P \leq 0.05$) different by pairwise t tests from the analysis of the mixed model for the attribute.

^x n.d. = no data

Table 6. Generalized least-squares means sensory rating scores for desirability among 19 apple cultivars grown at seven planting sites in the eastern United States in the 1995 NE-183 Multidisciplinary Apple Cultivar Evaluation Regional Project for the years 1998 through 2000.

Cultivar/selection	Mean desirability rating score ^z						
	Burlington VT	Belchertown MA	Geneva NYG	Rock Springs PAR	Biglerville PAB	Kearneysville WV	Kearneysville WVD
Arlet	3.1 de ^y	3.5 bcd	1.5 c	3.0 abcdefg	1.5 hij	2.8 cd	2.5 bcd
Braeburn	3.5 abcde	3.3 bcd	3.7 a	2.9 abcdefg	2.8 cdef	3.9 a	3.5 ab
Cameo	3.6 bcd	4.0 abc	3.0 ab	2.7 cdefg	1.9 ghij	3.1 abcd	3.0 abc
Creston	n.d. ^x	4.0 abc	3.0 ab	3.0 abcdefg	2.7 bcdefg	n.d.	2.1 cd
Enterprise	3.4 abcde	3.3 bcd	2.0 bc	3.0 bcdefg	2.0 fghij	3.8 ab	3.2 ab
Fortune	4.4 a	3.8 abc	3.1 abc	3.4 abcde	2.5 defg	n.d.	n.d.
Fuji Red Sport No. 2	n.d.	4.0 abc	n.d.	3.9 abcd	3.9 abc	3.5 abc	3.6 a
Gala Supreme	1.4 f	2.7 de	1.5 c	2.6 defg	1.9 ghij	1.8 e	1.9 d
Ginger Gold	4.0 abcd	4.3 abc	3.0 abc	3.5 abcdef	4.9 a	n.d.	n.d.
Golden Delicious	3.0 cde	3.7 abcd	3.3 a	4.0 a	3.4 bcd	3.0 bcd	4.0 a
Golden Supreme	4.1 abc	4.3 a	3.1 abc	3.8 abcde	3.7 ab	3.6 abc	3.7 a
GoldRush	2.6 def	2.1 e	3.0 ab	3.9 abcd	1.4 ij	3.9 ab	3.6 a
Honeycrisp	4.3 ab	4.1 abc	4.0 a	2.0 fg	2.6 defg	3.5 abcd	3.3 ab
NY 75414-1	4.1 abc	3.8 abc	3.7 a	3.8 abc	1.2 j	2.3 de	n.d.
Orin	2.5 ef	3.9 abc	3.0 ab	2.2 fg	2.4 efgh	2.2 de	2.8 abcd
Pristine	3.7 abcde	3.9 abcd	1.5 c	2.1 g	1.9 fghij	2.2 de	2.1 cd
Shizuka	2.9 bcdef	4.2 ab	3.7 a	3.9 ab	2.0 efghij	n.d.	3.7 a
Suncrisp	3.7 abcde	3.2 cd	3.3 a	2.5 efg	2.4 efghi	4.3 a	3.2 ab
Sunrise	3.9 abcd	3.6 abcd	2.0 bc	3.1 bcdefg	3.4 bcde	2.9 bcd	3.0 abcd
Avg.	3.4	3.7	2.8	3.1	2.6	3.1	3.1

^z Attribute ratings based on a bipolar hedonic scale where 1 = dislike, 2 = dislike slightly, 3 = like, 4 = like very much, and 5 = like extremely

^y Means for the same location not sharing a common following letter are significantly ($P \leq 0.05$) different by pairwise t tests from the analysis of the mixed model for the attribute.

^x n.d. = no data

6). The standard cultivar 'Golden Delicious' received the highest desirability rating at the PAR and WVD sites. This may be related to the tradition of this cultivar as an important commercial processing apple in these planting areas. At the PAB site 'Ginger Gold' was rated significantly above all other cultivars except 'Fuji' (Table 6). 'Ginger Gold' also received high ratings at the other sites that reported data for this cultivar (Table 6). At the WV site 'Suncrisp' was rated highest among 15 cultivars ('Creston' and 'Shizuka' were not planted at this site and 'Fortune' and 'Ginger Gold' were harvested outside the accepted SI range), but was followed closely by 'GoldRush', 'Braeburn', and 'Enterprise'. 'GoldRush' and 'Enterprise' appear to be well adapted to the warmer climate and longer growing season in the WV area. In addition, the field immunity to the apple scab fungus, *Venturia inaequalis* (Cke.) Wint., is an added benefit for these two cultivars (8, 9) in a region where apple scab is prevalent. Among the 19 cultivars evaluated, 'Gala Supreme' received the lowest desirability rating at four of seven sites and it did not rate significantly better than the lowest rating at the remaining three sites (Table 6). 'Gala Supreme', a chance seedling, may be downgraded because of its tendency to develop large rough lenticels, striped rather than blush red color, and a greasy skin. At the NYG site 'Arlet' and 'Pristine' were scored with equal dislike to 'Gala Supreme'. The problem with excess russet formation by 'Arlet' has been mentioned. 'Arlet' also received a low rating at the PAB site.

The generalized least-squares means sensory rating scores for flavor among the 19 cultivars at the seven sites are presented in Table 7. Flavor is a blend of taste and aroma (or smell) sensations and individual preferences can vary significantly between tasters. It is not unexpected that preference flavor scores varied among the seven sites in this study. At the same time there were some similarities across sites in a few cultivars. 'Golden Supreme' scored above 3.0 at all sites and was scored highest at the NYG and PAB sites. 'Honeycrisp' also scored above a 3.0 for flavor at all sites except the WVD site and it received the highest score at the VT site. 'Honeycrisp' has a mild subacid flavor (14) especially when grown in warmer climates

(2), but has been characterized with a more intense flavor when grown in cooler northern climates (11). Our findings would tend to support this characterization of 'Honeycrisp' flavor development. In addition, 'Honeycrisp' has been shown to ripen unevenly (29) and requires spot picking for best quality (31). Perhaps the samples in our study had not reached optimum flavor when harvested. 'Shizuka' scored just below "like extremely" at the MA site, but rated in the dislike slightly range at the PAB and VT sites. 'Sunrise', a very early maturing cultivar (24), was scored highest among cultivars at the PAB site. At the VT and MA sites, mean flavor score for 'Sunrise' did not differ from the highest rated cultivars. The WVD site assigned the highest flavor score to 'Orin' (Table 7), a sweet, but rather unattractive cultivar (Table 5). 'Fortune', a large cultivar that originated from the Cornell University breeding program, generally received high ratings for flavor, especially from the more northern planting sites.

In general, 'GoldRush' received low scores for flavor and was rated the lowest at the MA, WV, and WVD sites (Table 7). 'GoldRush' is a late season cultivar with very high acidity (9, 24) producing a tart flavor at harvest (16) that moderates to produce a more balanced flavor after 2 to 3 months in storage (9). 'Pristine', another cultivar with high acidity (24) received low scores for flavor at the NYG, WVD, PAR, and PAB sites. Other cultivars that scored low for flavor included 'Gala Supreme' at the VT site, NY 75414-1 at PAB, and 'Sunrise' at the WV site. 'Gala Supreme' also scored low at the two WV sites.

Previous analysis of the titratable acidity (TA) for the cultivars in this study showed that 'GoldRush' and 'Pristine' had significantly higher TA than all other cultivars, while 'Orin' and 'Fuji' had significantly lower TA than all other cultivars except 'Ginger Gold' (24). Sensory scores in this study for the intensity of acidic flavor (Table 8) tend to concur with the objective measure of TA in the previous study of quality factors (24). 'GoldRush' was rated near highly acidic at one site (NYG) and near or fully acidic at the remaining six sites. 'Pristine' scored as near acidic or above at all sites, except VT. 'Orin' and 'Fuji' were scored as weakly acidic or lower at all sites except

Table 7. Generalized least-squares means sensory rating scores for flavor among 19 apple cultivars grown at seven planting sites in the eastern United States in the 1995 NE-183 Multidisciplinary Apple Cultivar Evaluation Regional Project for the years 1998 through 2000.

Cultivar/selection	Mean flavor rating score ^z						
	Burlington VT	Belchertown MA	Geneva NYG	Rock Springs PAR	Biglerville PAB	Kearneysville WV	Kearneysville WVD
Arlet	3.3 bc	3.4 de	3.5 abc	3.3 ab	1.7 efg	3.0 abcde	2.4 cd
Braeburn	4.0 abc	3.3 de	3.3 abc	2.9 abc	2.9 abcd	3.8 a	3.3 abc
Cameo	3.4 bc	4.0 abcde	2.9 abcd	2.7 abc	2.4 cdef	2.7 bcde	2.9 abcd
Creston	n.d. ^x	4.5 abc	3.4 abc	2.8 abc	3.5 ab	n.d.	2.0 d
Enterprise	3.4 abcd	3.2 de	2.3 cd	2.7 bc	2.0 defg	3.2 abcd	2.9 abcd
Fortune	4.3 ab	3.8 abcde	4.2 ab	3.1 ab	2.9 abcd	n.d.	n.d.
Fuji Red Sport No. 2	n.d.	3.9 abcde	n.d.	2.8 abc	3.5 abc	3.4 ab	3.0 abcd
Gala Supreme	1.9 d	3.0 ef	2.6 bcd	2.9 abc	3.1 abc	2.3 cde	2.0 d
Ginger Gold	4.1 abc	4.4 abcd	2.0 cd	3.2 abc	3.1 abcd	n.d.	n.d.
Golden Delicious	3.1 bcd	3.4 cde	3.7 ab	3.6 ab	3.2 abc	3.0 abcde	3.6 abc
Golden Supreme	4.0 abc	4.4 ab	4.2 ab	3.9 ab	3.5 ab	3.6 ab	3.4 abc
GoldRush	2.9 cd	2.1 f	2.7 bcd	3.2 abc	1.7 fg	2.2 de	2.0 d
Honeycrisp	4.5 a	3.9 abcde	4.0 a	3.0 abc	3.5 ab	3.6 abc	2.7 bcd
NY 75414-1	4.1 abc	3.6 bcde	3.7 ab	3.7 a	1.2 g	2.3 cde	n.d.
Orin	3.1 cd	3.8 abcde	3.0 abc	3.5 ab	2.8 bcd	2.6 bcde	3.9 a
Pristine	3.7 abc	3.8 abcde	1.6 d	1.9 c	2.0 defg	2.2 de	2.1 d
Shizuka	2.9 bcd	4.7 a	3.7 ab	3.6 ab	2.3 bcdefg	n.d.	3.7 ab
Suncrisp	4.0 abc	3.2 de	4.0 a	2.7 abc	2.8 abcde	3.4 abcde	3.4 abc
Sunrise	3.5 abc	3.7 abcde	2.3 cd	2.9 abc	3.9 a	2.2 e	2.8 abcd
Avg.	3.5	3.7	3.2	3.1	2.7	2.9	2.9

^z Attribute ratings based on a bipolar hedonic scale where 1 = dislike, 2 = dislike slightly, 3 = like, 4 = like very much, and 5 = like extremely

^y Means for the same location not sharing a common following letter are significantly ($P \leq 0.05$) different by pairwise t tests from the analysis of the mixed model for the attribute.

^x n.d. = no data

Table 8. Generalized least-squares means sensory rating scores for acidity among 19 apple cultivars grown at seven planting sites in the eastern United States in the 1995 NE-183 Multidisciplinary Apple Cultivar Evaluation Regional Project for the years 1998 through 2000.

Cultivar/selection	Mean desirability rating score ^z						
	Burlington VT	Belchertown MA	Geneva NYG	Rock Springs PAR	Biglerville PAB	Kearneysville WV	Kearneysville WVD
Arlet	3.1 de ^y	3.5 bcd	1.5 c	3.0 abcdefg	1.5 hij	2.8 cd	2.5 bcd
Braeburn	3.5 abcde	3.3 bcd	3.7 a	2.9 abcdefg	2.8 cdef	3.9 a	3.5 ab
Cameo	3.6 bcd	4.0 abc	3.0 ab	2.7 cdefg	1.9 ghij	3.1 abcd	3.0 abc
Creston	n.d. ^x	4.0 abc	3.0 ab	3.0 abcdefg	2.7 bcdefg	n.d.	2.1 cd
Enterprise	3.4 abcde	3.3 bcd	2.0 bc	3.0 bcdefg	2.0 fghij	3.8 ab	3.2 ab
Fortune	4.4 a	3.8 abc	3.1 abc	3.4 abcde	2.5 defg	n.d.	n.d.
Fuji Red Sport No. 2	n.d.	4.0 abc	n.d.	3.9 abcd	3.9 abc	3.5 abc	3.6 a
Gala Supreme	1.4 f	2.7 de	1.5 c	2.6 defg	1.9 ghij	1.8 e	1.9 d
Ginger Gold	4.0 abcd	4.3 abc	3.0 abc	3.5 abcdef	4.9 a	n.d.	n.d.
Golden Delicious	3.0 cde	3.7 abcd	3.3 a	4.0 a	3.4 bcd	3.0 bcd	4.0 a
Golden Supreme	4.1 abc	4.3 a	3.1 abc	3.8 abcde	3.7 ab	3.6 abc	3.7 a
GoldRush	2.6 def	2.1 e	3.0 ab	3.9 abcd	1.4 ij	3.9 ab	3.6 a
Honeycrisp	4.3 ab	4.1 abc	4.0 a	2.0 fg	2.6 defg	3.5 abcd	3.3 ab
NY 75414-1	4.1 abc	3.8 abc	3.7 a	3.8 abc	1.2 j	2.3 de	n.d.
Orin	2.5 ef	3.9 abc	3.0 ab	2.2 fg	2.4 efgh	2.2 de	2.8 abcd
Pristine	3.7 abcde	3.9 abcd	1.5 c	2.1 g	1.9 fghij	2.2 de	2.1 cd
Shizuka	2.9 bcdef	4.2 ab	3.7 a	3.9 ab	2.0 efghij	n.d.	3.7 a
Suncrisp	3.7 abcde	3.2 cd	3.3 a	2.5 efg	2.4 efghi	4.3 a	3.2 ab
Sunrise	3.9 abcd	3.6 abcd	2.0 bc	3.1 bcdefg	3.4 bcde	2.9 bcd	3.0 abcd
Avg.	3.4	3.7	2.8	3.1	2.6	3.1	3.1

^z Attribute ratings based on a bipolar hedonic scale where 1 = dislike, 2 = dislike slightly, 3 = like, 4 = like very much, and 5 = like extremely

^y Means for the same location not sharing a common following letter are significantly ($P \leq 0.05$) different by pairwise t tests from the analysis of the mixed model for the attribute.

^x n.d. = no data

MA, where 'Fuji' was weakly to moderately acidic (Table 8). Other cultivars that scored moderately acidic to fully acidic and were not statistically different from the most acidic cultivars included 'Suncrisp' at six sites, 'Arlet' at five sites, 'Braeburn', 'Honeycrisp' and NY75414-1 at four sites, and 'Enterprise' at three sites.

BC planting site. Standard cultivars for comparison at this site included 'Royal Gala', 'Fuji' or 'Golden Delicious'. Except for 'Fortune', 'GoldRush' and 'Orin' panelists rated the visual appearance of the selected standard cultivar above the test cultivar (Table 9). Interestingly, in no comparison was the test cultivar rated fully above the "neither like nor dislike" score (5.0 to 5.9). It is obvious from the appearance liking scores that 'Royal Gala' is considered an attractive apple when grown in the BC area and offers formidable competition for new cultivars with regard to appearance, at least at this growing location. Based on liking scores of panelists (Table 9), visual appeal for 'Arlet' appeared superior to that reported by many sites in the eastern U.S. This is probably associated with the tendency for 'Arlet' to develop russet in warm, humid environments (16, 24). In BC, 'Arlet' had only a minor amount of calyx-end russet. The visual appeal for 'Fuji' was one of dislike slightly to dislike moderately, which was similar to the ratings for attractiveness at the more southern growing sites among the eastern U.S. planting sites (Table 5). It should be noted that two cultivars, 'GoldRush' and 'Orin', that produce rather conspicuous rough russeted lenticels (16) when grown in the eastern U.S., and especially in the mid-Atlantic region, (4, 13, 23), were rated slightly better for appearance than 'Fuji', a very popular commercial cultivar. In BC, lenticels were noticeable, but not large or russeted on 'GoldRush' and 'Orin'. 'Orin' in particular had a very smooth finish when grown in BC (C. Hampson, personal observation). 'Yataka Fuji' received the lowest hedonic rating score among all the cultivars tested for appearance (Table 9). 'Yataka', like 'Fuji', can have a very pale striped color, almost a "muddy" pink that detracts from its appearance (S. Miller and C. Hampson, personal observation).

Panelists preferred the texture of 'Creston', 'Honeycrisp', 'Orin', 'Suncrisp' and 'Yataka

'Fuji' over the respective standard cultivar(s) (Table 9). The texture of 'Cameo' after a mean of 62 d storage was rated below that of 'Fuji' at 65 d storage, but better than 'Royal Gala' after 96 d of storage. These ratings are probably related to the excellent storage qualities of 'Fuji' compared to the more moderate storage qualities of 'Royal Gala'; the storage quality of 'Cameo' has been reported as variable from several months (13) to considerably longer (16, 23). The significantly lower texture liking score for 'Ginger Gold' compared to 'Royal Gala' is likely related to time in storage. 'Ginger Gold' softens more quickly in storage than 'Royal Gala'. It can be speculated that once 'Ginger Gold' loses crispness that flesh firmness is not sufficient to maintain an acceptable texture. The texture for 'Arlet' was judged no different than 'Royal Gala' following a similar period of storage. Similarly 'GoldRush' was rated no different from 'Fuji' and the texture of 'Golden Supreme' was rated equal to that of 'Golden Delicious' after a period of cold storage. 'GoldRush' and 'Fuji' are late maturing cultivars with exceptional storage qualities (16) and the period of storage in these tests may not have been long enough to detect differences.

The flavor of 'Orin' and 'Yataka Fuji' was rated near a "like slightly" score and better than 'Fuji' and 'Golden Delicious', respectively (Table 9). Panelists rated 'Cameo' and 'Creston' flavor above that of 'Royal Gala', but no different than 'Fuji', however, the 'Royal Gala' had been held in storage for a longer period of time than the test cultivars, especially in the case of 'Cameo'. The low rating for 'Honeycrisp' is somewhat surprising given the widespread acceptance and claims of superior quality for this cultivar (14, 33). However, 'Honeycrisp' has been reported to develop an "off" flavor in storage when fruit are harvested in a later stage of maturity (14, 29), which may explain the lower flavor score in the BC evaluation. In general, flavor liking of the test cultivars at BC compared with liking scores from eastern U.S. sites except for 'Golden Supreme'. Many eastern U.S. cooperators rated the flavor of 'Golden Supreme' as "like very much" (Table 7) while panelists in BC assigned a mean flavor score of 4.4, "dislike slightly" (Table 9).

Intensity ratings for selected sensory

Table 9. Weighted mean hedonic scores for comparisons of standard cultivars ('Fuji', 'Golden Delicious' or 'Royal Gala') with NE-183 test cultivars in BC, number of years that taste panels were run against the standard, and range (mean) of days in storage prior to taste panel. All comparisons are significantly different unless indicated otherwise.

Cultivar	Appearance	Texture	Flavor	No. of years	Days in storage
Arlet	5.7	6.1	5.6		48-66 (53)
Royal Gala (s) ^z	6.9	6.1 ^z	5.8	5	48-62 (51)
Cameo	5.0	5.4	5.2		43-81 (62)
Fuji (s)	4.1	5.8	5.1 ^z	2	50-79 (65)
Royal Gala (s)	6.8	4.7	4.8	2	78-113 (96)
Creston	4.8	6.3	6.2		37-64 (50)
Fuji (s)	4.1	6.6	6.0 ^z	2	18-63 (41)
Royal Gala (s)	6.7	5.6	5.6	5	48-97 (66)
Fortune	4.6	5.8	5.3		50-57 (54)
Fuji (s)	3.9	6.3	5.4 ^z	2	50-59 (55)
Ginger Gold	5.3	3.9	4.4		51-57 (54)
Royal Gala (s)	6.8	5.5	5.3	2	42-48 (45)
GoldRush	4.5	6.4	4.9		36-66 (48)
Fuji (s)	4.3	6.4 ^z	5.7	3	49-80 (59)
Golden Supreme	5.0	5.0	4.4		37-84 (61)
Golden Delicious (s)	5.4	5.0 ^z	5.2	2	34-64 (49)
Honeycrisp	4.3	6.2	4.6		48-90 (62)
Royal Gala (s)	7.1	5.6	5.3	3	48-83 (61)
NY 75414-4	5.0	4.3	4.9		37-49 (43)
Golden Delicious (s)	5.4	4.9	5.2 ^z	2	34-64 (49)
Orin	4.9	6.3	5.8		57-90 (68)
Fuji (s)	4.2	6.1	5.2	2	41-84 (59)
Suncrisp	4.5	5.7	5.2		49-50 (50)
Golden Delicious (s)	5.4	3.7	5.0 ^z	2	64-68 (66)
Yataka Fuji	3.8	5.7	5.9		43-84 (64)
Golden Delicious (s)	5.4	4.9	5.2	2	34-64 (49)

^z The score for this standard (s) cultivar is not significantly different from the adjacent NE-183 cultivar by t-test (5% level).

attributes and comparison of the test cultivar to a standard cultivar are illustrated as polar plots in Fig. 1. Among the seven test cultivars evaluated, 'GoldRush' when compared to 'Fuji', showed the greatest number of differences in the selected attributes. 'GoldRush' was perceived to be a more aromatic apple with a tougher skin, harder flesh and greater sourness, but with less sweetness and less juiciness than 'Fuji'.

The 'GoldRush' apples were evaluated after only 61 d storage, which may not have been sufficient time to achieve maximum soluble solids and full flavor (9). Panelists perceived minimal differences in the sensory attributes between 'Ginger Gold' and 'Royal Gala', and 'Yataka' and 'Royal Gala'. Both 'Ginger Gold' and 'Royal Gala' are early maturing cultivars and were evaluated after about one month storage (24 and 32 d respectively).

However, it is interesting to note that taste panelists apparently could detect the rapid softening which occurs in ‘Ginger Gold’ compared to ‘Royal Gala’ (Fig. 1). Despite significant differences for 5 of the 7 sensory attributes when ‘Creston’ was compared with ‘Royal Gala’, a case for the practical significance between these two cultivars in this study is questionable.

Conclusions

The results in this study demonstrate the significant effect that cultivar and site can have on the sensory quality of apples. For a few sensory attributes, such as crispness, juiciness, or sweetness there was uniformity

in cultivar performance across the reporting sites and clear differences between cultivars. While differences did occur in crispness and sweetness across sites, these differences were minimal and may have little or no practical significance. However, many sensory attributes were affected by the interaction between site and cultivar, as might be expected. No single cultivar developed superior sensory qualities across all sites; likewise no one site consistently produced apple cultivars with superior sensory qualities. These results support the need for widespread systematic testing of new apple cultivars across many sites in order to ascertain performance under different soil and climatic conditions.

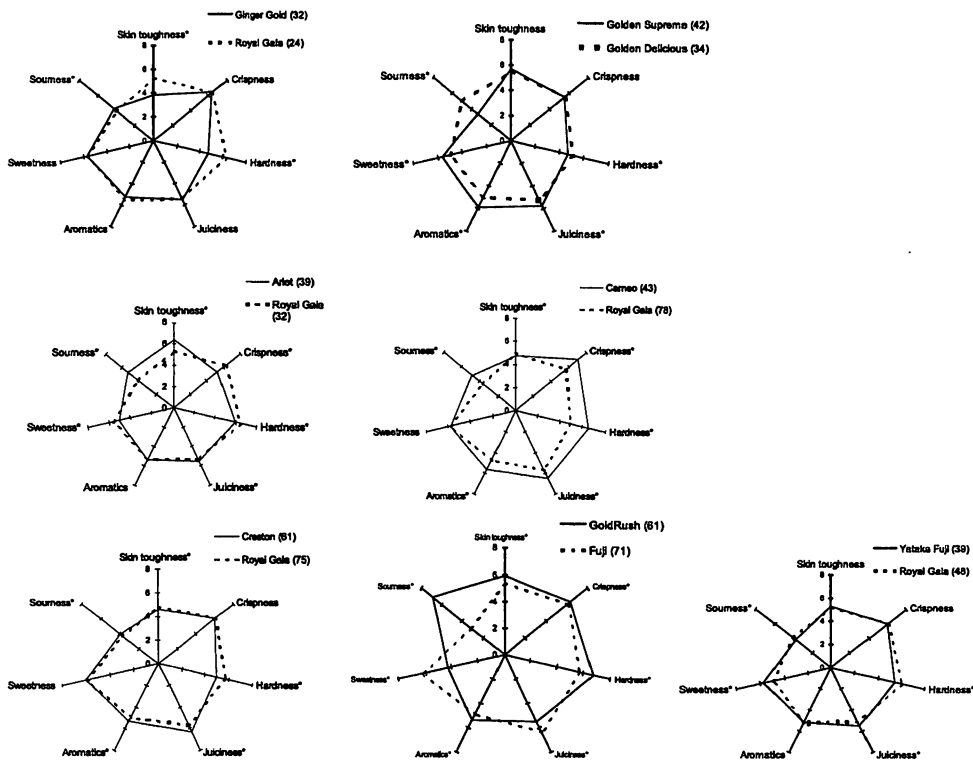


Figure 1. The perceived degree of skin toughness, crispness, hardness, juiciness, aromatic intensity, sweetness and sourness for seven apple cultivars in the 1995 NE-183 Regional Project planting in BC as determined by trained taste panels. The cultivars ‘Royal Gala’, ‘Golden Delicious’, and/or ‘Fuji’ are used as the standard for comparison. The mean number of days in storage prior to the taste tests is given in parentheses beside the cultivar name on each graph. Scale is a unipolar intensity rating where 0 = not detected, 3 = slight, 5 = moderate, and 7 = intense. The asterisk denotes that the two cultivars are significantly different by t-test at the 5% level.

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