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Fruit Quality of Spur-type and Nonspur-type 'Delicious' Apple Strains

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Abstract

Six strains of 'Delicious' apples (*Malus domestica* Borkh.) were evaluated over four seasons for color (peel and flesh), flesh firmness, soluble solids content (SSC), titratable acidity (TA), individual and total carbohydrate content and disorders. Fruit were evaluated at harvest and after controlled atmosphere storage. Strains were grouped based on spur-type ('Starkrimson', 'Starkspur Ultrared', 'Oregonspur II') vs. nonspur-type ('Early Red One', 'Topred', 'Classic') growth habit and compared. Spur-type apples as a group were more mature at harvest, but contained both less peel red color and less TA than nonspur-type apples. After CA storage, spur-type apples were firmer with a higher SSC/TA ratio despite significantly lower SSC and TA values. Spur-type fruit also displayed a more green-colored flesh and little or no peel color difference depending on storage term. Nonspur-type 'Delicious' apples from both WA and ID had higher sucrose content per gram of flesh than spur-type apples. The proportion of the total carbohydrate content made up of sucrose was consistently greater for nonspur-type vs. spur-type fruit in both locations.

Effect of growth habit (spur-type vs. nonspur-type) on tree growth and productivity of different strains of 'Delicious' has been the subject of some research (10, 11, 24). However, growth-habit effects on fruit quality among 'Delicious' strains have not been clearly defined. Fruit quality differences among strains of 'Delicious' apples at harvest have been described by several investigators (8, 14, 15, 16, 23). Red color development was identified as the major quality difference among 'Delicious' strains in harvest evaluations (4, 7, 10, 11, 16). These reports included suggestions that spur-type strains tended to display redder skin color at harvest. When consumers were asked to distinguish among strains of 'Delicious' apples based on flavor, crispness and acceptability, skin color was the dominant distinguishing factor cited (6). Effects of growth habit on other parameters of 'Delicious' fruit quality have not been well documented at harvest (15) or following storage (19, 20).

Ketchie (16) reported differences in 'Delicious' fruit quality due to strain but did not distinguish between spur and nonspur growth habit effects. Ingle and D'-Souza (15) reported differences in total soluble solids levels in several 'Delicious' strains at harvest, but no reference was made to growth habit. Igesias et al. (14) observed firmness, soluble solids and titratable acidity differences among strains of 'Delicious', but did not specifically compare their results on the basis of growth habit.

A few reports suggest possible effects of growth habit on 'Delicious' fruit quality. Meheriuk and Porritt (20) reported that fruit of 'Starkrimson Delicious' (spur-type) were firmer than fruit of 'Harrold Red Delicious' (nonspur-type) after controlled atmosphere (CA) storage, but no differences related to growth habit were presented for SSC or acidity. Other reports (4, 21) suggested that spur-type 'Delicious' trees produced apples that were more elongated than apples from nonspur-

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type trees. Baugher et al. (4) found that apples from nonspur-type 'Delicious' trees at harvest had higher total soluble solids content than apples from spur-type trees.

Differences among strains of 'Delicious' in content of individual sugars have not been well documented. Carbohydrate composition of apples varies depending on cultivar, region of production, maturity, storage regime, processing method and various other horticultural practices (1, 2, 3, 9, 12, 17, 22, 23, 27). No reports have been found that compare 'Delicious' strains in terms of fruit content of individual sugars on the basis of growth habit.

This study was initiated to determine if consistent, measurable fruit quality differences can be distinguished in several commonly grown spur-type and nonspur-type 'Delicious' strains at harvest and following CA storage when compared over several years on the basis of growth habit.

Materials and Methods

'Delicious' apples were harvested in four successive years (1995, 1996, 1997, 1998) from three spur-type ('Starkrimson', 'Starkspur Ultrared' and 'Oregonspur II') and three nonspur-type ('Early Red One', 'Topred', and 'Classic') 'Delicious' strains grown in commercial orchards in two locations near Wenatchee, WA. The same orchards and trees were used each year. In one season (1996), trees of the same strains in an orchard located at the Univ. of Idaho Parma Research and Extension Center, Parma, ID were collected for a separate analysis of fruit content of several sugars. Seven days prior to commercial harvest and at commercial harvest each year (26), 50 apples of uniform size and color were collected at random from 3 single-tree plots of each strain in each location. Fruit from each strain, location and plot were kept separate during harvest, storage and post-storage evaluations. Immediately after harvest the apples were transported to the USDA-ARS Tree Fruit Research Laboratory in Wenatchee, WA. Upon arrival at the laboratory, the apples from each 50-fruit sample were divided at random into 3 groups. One group of 10 apples from each sample was used immediately to assess harvest maturity parameters. Two groups of 20 apples from each sample, harvest date and location were placed in CA storage. The CA atmosphere used in this study was 1% O_2 and 1% CO_2 (a standard commercial storage atmosphere for apples). CA atmospheres were established within 24 hours of harvest and were maintained throughout the storage period at ±0.1% using a computer control system (Technical Consulting Services, Chelan, WA). Nitrogen for this purge-type CA system was supplied by a membrane separation apparatus; bottled CO_2 was used to maintain appropriate CO_2 levels as necessary. All gases were humidified prior to injection. Fruit were held in CA at 1°C for 90 or 180 days before analysis of fruit quality parameters.

Post-storage quality was assessed on 20 apples from each strain, location, storage term, and replication. Ten apples were evaluated immediately after removal from storage and the remaining 10 were allowed to ripen for 7 days at ambient temperature (≈20°C) before evaluation. Quality factors evaluated included flesh firmness, total soluble solids content (SSC), titratable acidity (TA), external skin color, internal flesh color, and disorders (scald, bitter pit, watercore, internal breakdown). Individual sugars (sucrose, glucose, fructose, sorbitol) were determined on fruit from the Washington orchards in 1996 and 1997 and on fruit from the Idaho orchard in 1996. Firmness was determined randomly at two locations per fruit with the TA-XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY) equipped with a 11.1 mm probe. Single cross-sectional slices from each of the same 10 fruit were composited, ground, and 30 ml. of juice were taken for determination of SSC, TA and carbohydrates. An Abbé type refractometer with a sucrose scale calibrated at 20°C was used to determine SSC. TA was measured with a Radiometer titrator, model TTT 85 (Radiometer, Copenhagen, Denmark). Acids were titrated to pH 8.2 with 0.1N NaOH and expressed as percent malic acid. External and internal color were determined with The Color Machine

Table 1. Quality attributes of nonspur-type and spur-type 'Delicious' apple on two harvest dates over 4 years (1995-1998).

	Starch (1-5)	Firmness (N)	SSC (%)	Titratable Acidity (% malic)	SSC/TA ratio
Habit					
Nonspur-type	2.12b[z]	69.8a	11.4a	0.32a	36.2a
Spur-type	2.31a	70.8a	11.1a	0.31b	37.3a
Harvest Date					
1	2..04b	73.2a	10.9b	0.32a	34.4b
2	2.65a	66.7b	11.8a	0.30b	39.7a
Interactions					
Habit x Har.	ns	ns	ns	ns	ns

[z]Means within growth habit or harvest date not followed by a common letter are significantly different by analysis of variance ($P \leq 0.05$).

(Pacific Scientific, Silver Springs, MD) using the Hunter L*, a*, b* system and hue angle (h°) values calculated from observed a* and b* values (13). External color was measured on the equatorial plane on the two sides of each fruit 90° from the most exposed side. Carbohydrates were determined on Washington samples in 1996 and 1997 and in 1996 on samples from an orchard in Idaho by the high performance liquid chromatography method previously described (9).

The experiment employed a completely randomized design with a treatment arrangement each year of 2 locations in WA, 5 strains, 2 harvest dates, 2 storage terms, and 2 ripening times. Data from the three individual trees of each strain in each location in WA on each harvest date were averaged to produce a single plot mean value for each parameter measured. Plot means were then evaluated by analysis of variance using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS) program package (SAS, Inc., Cary, NC), using data from each year as replicates. Following the initial analyses of all 5 factors, the data were reanalysed without inclusion of the non-significant location effect. Strain effects were further evaluated by substituting a single degree-of-freedom comparison of growth habit (spur-type vs. nonspur-type) to assess the overall effect of growth habit on fruit quality parameters.

Results and Discussion

Using the starch index (26) as an indicator of maturity, apples from spur-type trees contained consistently less starch than apples from nonspur-type trees on the same harvest date (Table 1). There were no differences in firmness, SSC, or SSC/TA ratio at harvest between apples from spur-type and nonspur-type trees, but spur-type fruit tended to contain a slightly lower TA level. Though statistically significant, this difference in TA was small (0.01%) and would not be considered of any horticultural importance due to the lack of difference in the SSC/TA ratio. Fruit samples harvested one week later each year exhibited a loss in firmness, starch content and TA, accompanied by an increase in SSC and SSC/TA ratio, regardless of growth habit. Over this one week of additional time in the orchard, fruit experienced an average loss of 6.5N in firmness but a gain of 5.3 units in the SSC/TA ratio. These differences in major determinants of fruit quality might significantly affect consumer preference. A previous study (5) reported greater consumer acceptance of apples with increased SSC/TA ratios.

Color has long been considered a major factor in consumer choice of apples; differences in skin color of 'Delicious' strains have been reported (6). In this study, apples

Table 2. External and internal color of nonspur-type and spur-type 'Delicious' apple on two harvest dates over 4 years (1995-1998).

	External		Internal	
	L*	hue	L*	hue
Habit				
Nonspur-type	38.5a[z]	22.1b	74.6a	123.8a
Spur-type	40.5a	25.6a	74.9a	111.5a
Harvest date				
1	40.4b	24.7a	75.4a	127.5a
2	38.3a	22.8b	73.8b	104.5b
Interaction				
Habit x Har.	ns	ns	ns	ns

[z]Means within growth habit or harvest date not followed by a common letter are significantly different by analysis of variance ($P \leq 0.05$).

Table 3. Quality attributes of nonspur-type and spur-type 'Delicious' apples after 90 and 180 days of controlled atmosphere storage over 4 years as influenced by harvest date and ripening time (1995-1998).

	90 days				180 days			
	Firmness (N)	SSC (%)	Titratable Acidity (% malic)	SSC/TA ratio	Firmness (N)	SSC (%)	Titratable Acidity (% malic)	SSC/TA ratio
Habit								
Non-spur type	59.5b[Z]	13.2a	0.28a	47.7b	59.9b	13.4a	0.26a	52.1b
Spur-type	62.1a	12.7b	0.26b	49.6a	62.2a	13.2b	0.24b	54.8a
Harvest date								
1	62.9a	13.0a	0.29a	46.2b	64.1a	13.2a	0.26a	51.8b
2	57.9b	12.9a	0.25b	52.0a	57.6b	13.3a	0.24b	55.3a
Ripening time (days)								
0	64.8a	12.9a	0.28a	47.06b	61.7a	13.3a	0.25a	53.2a
7	56.7b	13.0a	0.26b	50.3a	60.4a	13.2a	0.25a	53.8a

[Z]Means within growth habit or harvest date not followed by a common letter are significantly different by analysis of variance ($P \leq 0.05$).

from nonspur-type trees were rated as darker red (based on significantly lower hue values) than apples from spur-type trees at harvest (Table 2). This difference in skin color is noteworthy given the observation that apples from spur-type trees were considered more mature at harvest based on the starch index. There were no differences in internal flesh color at harvest based on growth habit. While fruit were consistently more red on the second harvest date regardless of strain, there was no interactive effect of growth habit and harvest date on either external or internal color at harvest.

After 90 or 180 days in CA storage, apples from spur-type trees were firmer, with lower SSC and TA values but with a higher SSC/TA ratio, than apples from nonspur-type trees (Table 3). The observed difference in firmness (>2.0N) between spur-type and nonspur-type apples was enough to be considered economically important, even though after 180 days of CA storage, apples from both growth-habit categories exceeded the 53N minimum firmness required to meet Washington State grade standards (25). Increased firmness, coupled with a higher SSC/TA ratio, would

Table 4. External and internal color of nonspur-type and spur-type 'Delicious' apples after 90 and 180 days of controlled atmosphere storage over 4 years as influenced by harvest date and ripening time (1995-1998).

	90 days				180 days			
	External		Internal		External		Internal	
	L*	hue	L*	hue	L*	hue	L*	hue
Habit								
Non-spur type	39.4a[Z]	22.2b	72.9a	105.9b	40.1a	25.9a	75.7a	115.4a
Spur-type	40.8a	25.5a	73.4a	127.1a	40.4a	26.5a	75.9a	119.8a
Harvest date								
1	40.2a	24.0a	72.0a	129.0a	41.2a	27.5a	75.7a	129.5a
2	39.9a	23.5a	74.8a	97.7b	39.1b	26.4b	75.8a	103.9b
Ripening time (days)								
0	41.0a	22.6b	72.7a	117.7a	40.1a	23.7b	75.8a	112.9b
7	39.1a	25.1a	73.6	115.3a	40.4a	29.0a	75.6a	122.9a

[Z]Means within growth habit or harvest date not followed by a common letter are significantly different by analysis of variance ($P \leq 0.05$).

Table 5. Carbohydrate content at harvest of non-spur-type and spur-type 'Delicious' apples grown in Washington and Idaho.

	Carbohydrate content (mgg^{-1} flesh)					
	Fructose	Glucose	Sucrose	Sorbitol	Total	Sucrose (%)
			Washington, 1996 and 1997			
Habit						
Nonspur-type	6.78a[Z]	2.70a	1.87a	0.18a	11.55a	16.57a
Spur-type	6.57b	2.80a	1.52b	0.15a	11.05b	14.32b
Harvest date						
1	6.69b	2.85a	1.47b	0.09b	11.11b	13.44b
1	7.06a	2.92a	1.79a	0.17a	11.96a	15.50b
			Idaho, 1996			
Habit						
Nonspur-type	5.28a	2.22b	2.90a	0.22a	10.62a	27.20a
Spur-type	5.21a	2.47a	2.49b	0.17a	10.35a	24.49b
Harvest date						
1	4.29b	1.84a	2.39b	0.09a	8.85b	25.7b
2	6.21a	2.81a	3.08a	0.31a	12.18a	27.7a

[Z]Means within growth habit or harvest date not followed by a common letter are significantly different by analysis of variance ($P \leq 0.05$).

be expected to have a favorable influence on consumer acceptance. Differences in SSC among strains of 'Delicious' have been reported (4, 14). Meheriuk and Porritt (20) reported that fruit from nonspur-type trees were higher in SSC than fruit from spur-type trees, but significant differences were not evident until after storage. In this study, a 7-day ripening period also resulted in reduced flesh firmness and TA, no effect on SSC and an increase in the SSC/TA ratio independent of growth habit or harvest date. After 90 or 180 days of CA storage followed by 7 days of ripening, fruit quality attributes were acceptable for 'Delicious' apples in this study regardless of growth habit.

After 90 days of CA storage, nonspur-type fruit exhibited more red skin color and more yellow internal flesh color (based on significantly different hue values) than spur-type fruit (Table 4). After 180 days of CA storage, however, the differences in external and internal color observed at harvest and after 90 days of storage were no longer detectable. Differences in external color between spur-type and nonspur-type 'Delicious' apples prior to and at harvest have been reported previously (23), but no reports are known regarding skin or flesh color after storage. The results of this study suggest that growth-habit-based differences in external and internal color may not be significant after long-term CA storage.

Harvesting fruit one week later had no effect on peel color after 90 days of CA storage; after 180 days of CA storage, later-harvested fruit displayed a darker red peel color (Table 4). An increase in red color is normally observed with later harvest dates. After both 90 and 180 days of CA storage, later-harvested apples displayed less green flesh color than apples harvested one week earlier. This pattern of color change is also expected.

Differences in the content of individual carbohydrates in 'Delicious' apples have not been documented. In this study, nonspur-type 'Delicious' apples from both WA and ID had higher sucrose content per gram of flesh at harvest than spur-type apples from the same location (Table 5). The proportion of the total carbohydrate content made up of sucrose was also consistently greater in nonspur-type vs. spur-type fruit in both locations. The higher fructose level observed in spur-type fruit in WA over two years was not found in apples grown in ID in 1996. No differences in other individual sugars could be related to growth habit. Total carbohydrate con-

tent was higher in nonspur-type vs. spur-type apples in WA. In ID fruit, the total carbohydrate content was not significantly different due to growth habit, but the pattern was the same as in WA fruit. Higher amounts of sucrose in nonspur-type apples at harvest might beneficially affect post-storage flavor, given that sucrose contributes a sweeter taste than other sugars found in apples, with the exception of fructose.

Incidence of disorders (scald, brown core, watercore, bitter pit) was very low in all samples throughout this study (data not shown). No differences in incidence of disorders could be related to growth habit.

Conclusions

Consistent differences in various measures of fruit quality between spur-type and nonspur 'Delicious' apples were found both at harvest and after CA storage over the four years of this study. Spur-type apples contained less starch at harvest. However, non-spur apples exhibited more red peel color and slightly more TA than spur-type fruit. After CA storage, spur-type apples were significantly firmer with a higher SSC/TA ratio and more green flesh color, but with lower SSC and TA, and very little peel color difference. The advantage in firmness and SSC/TA ratio for spur-type apples might enhance their comparative consumer appeal relative to nonspur types. On the other hand, nonspur-type apples might have greater consumer appeal if elevated sucrose and fructose levels and a less green flesh color contribute significantly to consumer preference. Only a detailed organoleptic analysis program comparing several nonspur-type vs. spur-type 'Delicious' strains can finally resolve this issue.

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POMOLOGICAL TRAITS OF 'SU' CHERRY LAUREL

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Abstract

This study was carried out to determine the pomological traits of 'Su' cherry laurel (*Prunus laurocerasus*) as grown in Trabzon (Turkey) province in 1999, 2000 and 2001. Cluster weight, number of fruit per cluster, fruit weight, stone weight, soluble solids, pH and titrable acid content were determined as 46.75 g, 9.85, 4.89 g, 0.37 g, 15.92 %, 4.55 and 0.29 %, respectively. 'Su' is promising cultivar for the province as table cultivar due to its pomological characteristics. This cultivar is better than others because of it is very juicy and attractive color for skin and flesh.

Introduction

Compared to the surface area of the world, Turkey is very minute. However, there is great variation in the ecological conditions within Turkey which allows for a very wide range of horticultural crops to be grown. Turkey is between 36-42 North latitudes and 26-45 East longitudes.

In the coastal area of the Black Sea Region (Northern Turkey), there are many different local fruit species and varieties. In the Trabzon province, the annual precipitation is 833.8 mm, which falls through out the year. The relative humidity is 74.67 %. Annual mean temperature is 14.6 °C, and there is not freeze (2). Trabzon province has 4685 km^2 area.

One of the centers of origins of cherry laurel is the Eastern Black Sea Region (3). Cherry laurel is consumed fresh, dried, in jams, marmalades, canned or pickled. The leaves and seed of this fruit species are

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