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Evaluation of Quality Traits and Yield of 28 Strains of 'Delicious' Apple

W. D. LANE,[1] R. A. MACDONALD[1] AND D. O. KETCHIE[2]

Abstract

Traits contributing to yield and fruit quality of 28 spur and standard growth habit strains of 'Delicious' apple (*Malus domestica* Borkh.) were studied. Cumulative per tree yield to seventh leaf (precocity) was consistently greater in the spur strains averaging 33.7 kg compared to 20.4 kg for standard strains. Mature tree yield was nearly equal for the two tree types but average yield efficiency was higher for the spur strains. This was reflected in higher calculated per hectare yields (45.1 compared to 28.8 tonnes). Color and size grades were determined on a commercial grading line. The standard strain 'Early Red One' was notable as the best coloring strain and also had a higher efficiency ratio than other standard strains in the fifth crop. Color of strains ranged from a high of 59% to 0% (B.C. extra fancy) with most spur strains developing less color than standard ones; but the spur strains 'Ace,' 'Red King Oregon Spur' and 'Improved Ryan Spur' were highly ranked for color. The spur strains with poorer color also had smaller fruit. 'Red King Oregon Spur' and 'Aomori' had larger fruit than other strains. Fruit shape, seed number, soluble solids and flesh firmness of strains varied less than color and yield determining traits.

Introduction

The 'Delicious' cultivar consists of more than 150 strains which originated by mutation. These were catalogued and described by Ballard (2) and Fisher and Ketchie (9). 'Delicious' accounts for approximately 42% of North American apple production (1), resulting in interest in strains with potential to improve production efficiency and quality (size and color).

Strains of 'Delicious' vary in growth habit (15) and several studies have compared traits of spur growth habit to standard strains. Spur strains have a greater number of fruit spurs per branch than standard strains (12). Spur strains of 'McIntosh' can be distinguished from standard strains and defined for degree of spurriness by the percent of axillary buds on previous season's shoots which break dormancy the following spring (14), and spur strains usually have smaller trunk cross section area. These differences parallel others in yield/tree and yield efficiency of strains but environment appears to interact with strain (8, 19). Other components describing spur habit strains, such as bud diameter, spur density and trunk cross section area have been correlated with yield efficiency (19), indicating that strains differ in adaptability to regional environments.

More red color, greater size and firmness and higher yields increase the commercial value of strains. Crassweller et al. (4) described differences in color of 17 strains. Ketchie (13) evaluated some production and fruit traits of 'Delicious' strains grown at Wenatchee, Washington, on M.7 EMLA rootstocks and found that they ranged in yield from 1.8 to 21 kg/tree with canopy diameters of six-year-old trees from 0.5 m to 2.5 m. Fallahi et al. (8) studied productivity and post harvest quality of 26 strains and found differences in many traits including colour and firmness.

The objective of our study was to evaluate tree production and fruit quality traits of 16 spur and 12 standard strains when grown in British Columbia. Precocity, yield, yield efficiency and tree size were evaluated. In the last year of the study, fruit were graded on a commercial packing line to evalu-

[1]Agriculture and Agri-Food Canada Research Centre, Summerland, British Columbia V0H 1Z0. Contribution No. 904.
[2]Tree Fruit Research and Extension Centre, Washington State University, Wenatchee, Washington, 98801, USA.

ate size and color. °Brix and titratable acidity, shape and flesh firmness of strains were measured. The results illustrate differences between strains within this cultivar when grown close to its Northern limit and will help predict the commercial performance of young trees of these 'Delicious' strains.

Materials and Methods

The trees, all propagated at one location, were planted in March 1980 at the Summerland Research Station. Similar plantings of these trees were established in Idaho, Indiana, Oregon and Washington. The planting consisted of 28 'Delicious' (*Malus domestica* Borkh.) strains (Table 1) with six single tree plots of each strain on both M.7 EMLA and MM.111 EMLA rootstock in a completely randomized design. Spacing was 4.9 m between rows and 3.7 m between trees within the row. The pollinizer cultivar was 'Idared,' every third tree in every third row. Soil type was a Skaha sandy loam (11) pH 6.9, the elevation 350 meters and mean growing degree days 2129 (5°C basis, 29 year average). Irrigation was from an under-tree system. Trees were trained to the Pacific Northwest Central Leader system (10). Standard commercial management practices recommended for the area were followed including chemical thinning at blossom time followed by hand thinning in June. Fruit was picked within a week of the commercial picking opening date for Summerland.

Precocity and yield. Yield, tree and fruit traits were measured from the fourth to the eighth leaf. The trees were considered mature in their eighth leaf, when their size could be maintained by containment pruning. Precocity was determined by the yield in the first four cropping years. Trees were evaluated in the eighth leaf for yield to indicate the crop load of mature trees. Fruit samples from these trees were taken for the evaluation of quality traits and as an indication of strain yield from mature trees. Bloom score from 1 to 100 was taken in the ninth leaf (Table 2) to confirm that trees were not in a biennial habit and to indicate they were not over cropped in the eighth leaf. Tree width was determined from the mean extension of the four basal scaffold branches. Yield efficiency was calculated from the yield/tree divided by their trunk cross section area. Calculation of density (trees/ha) was derived from mean tree diameter of each strain plus approximately 0.5 m in the row and an additional 2 m alley between rows.

Fruit quality. Fruit quality traits were determined by evaluating one bin (approximately 390 kg or 1550 fruit) of each strain except 'Starkspur Ultra Red.' The fruit were segregated into nine size categories based on fruit number per 19.2 kg box (56, 64, 72, 80, 88, 100, 113, 125 or 138). Mean fruit weight ranged from 342 g for size 56 to 139 g for size 138. The line segregated the fruit into five color grades plus culls. B.C. extra fancy required 90% or more solid red color. Percent unmarketable fruit was common grade plus culls.

Soluble solids (°Brix), titratable acidity as % malate (TA), fruit shape (length/diameter), seed number and flesh firmness were determined in a subsample of 60 fruit from a packed box of size 100 count (192 grams) B.C. extra fancy of each strain. °Brix and TA were from a composite sample of 2 sectors from each apple. °Brix was measured with a refractometer and TA by titration of a 10 ml sample to pH 8.2. Flesh firmness was determined on opposite sides of each apple (skin removed) using a penetrometer (model C LPT-11, Lake City Electronics, Kelowna, BC). Length and diameter were measured with callipers and seeds of each apple counted. 'Starkspur Ultra Red' and 'Aomori' were not included. Applicable results were analyzed using SAS's General Linear Model procedure (18).

Results

Rootstock effect. The M.7 EMLA and M.111 EMLA trees in this study were of similar size by the eighth leaf; mean trunk diameter on M.7 EMLA and M.111 EMLA was 8.7 cm and 8.9 cm, respectively. Precocity and yield efficiency on the two rootstocks, to the seventh leaf were also similar with cumulative yield/tree for M.7 averaging nine percent more than M.111. We therefore analyzed our data across the rootstocks giving 12 rather than six single tree replicates per strain.

Precocity and yield. Cumulative yield to the seventh leaf ranged from 47 to 1.4 kg/tree (Table 1). The precocity of the spur strains was usually greater than the standards. Notable exceptions were 'Red Chief' and 'Starkspur Ultra Red.' The mean yield of all spur strains was 33.7 kg compared to 20.4 kg for standard strains. Yields were less than expected in the seventh

Table 1. Yield per tree (kg) of 'Delicious' strains, precocity (age 4-7) and cumulative yield from mature trees (eighth leaf).

Strain	Growth habit	Age (leaf)					
		4	5	6	7	4-7	8
Starking	Standard	2.3	6.2	8.8	11.2	28.4	82.9
Early Red One	Standard	2.4	6.9	10.5	10.6	30.2	81.9
Starkrimson	Spur	4.3	7.1	10.4	16.3	38.0	72.3
Red King Oregon Spur	Spur	4.3	7.9	8.8	14.3	35.2	70.8
Sharp Red	Standard	1.0	4.1	5.5	6.3	16.8	69.5
Wellspur	Spur	2.9	7.0	9.6	12.0	31.6	69.4
Ace	Spur	5.8	8.1	11.0	18.5	43.4	68.4
Redspur	Spur	4.3	6.2	7.9	11.1	29.5	68.3
Sturdeespur	Spur	3.7	4.5	25.9	12.7	46.7	67.9
Atwood	Spur	4.2	7.5	12.0	16.2	39.9	67.6
Imperial	Standard	2.6	6.2	6.0	6.2	21.0	67.0
August Red	Standard	1.9	4.9	8.5	11.1	26.4	66.2
Improved Ryan Spur	Spur	5.5	8.7	14.5	18.3	47.0	65.4
Classic Red	Standard	1.6	4.7	4.6	4.6	15.1	64.4
Hi-Early	Standard	1.0	4.0	5.4	5.8	16.2	63.8
Silver Spur	Spur	5.6	8.6	12.5	15.1	41.8	63.6
Rose Red	Standard	1.5	3.6	7.0	3.7	15.8	63.0
Apex	Spur	5.7	10.0	15.1	16.3	47.1	62.0
Topred	Standard	1.7	4.3	4.6	7.8	18.5	61.4
Starkspur Supreme	Spur	3.8	8.1	12.3	9.3	33.5	60.6
Hardi-Brite	Spur	3.9	7.0	9.5	10.2	30.6	54.1
Improved Ryanred	Standard	1.8	5.1	6.5	6.2	19.6	53.4
Redchief (Campbell)	Spur	1.3	3.1	5.1	7.2	16.7	53.2
Spured Royal	Spur	4.7	7.8	9.8	13.0	35.3	52.8
Hardispur	Spur	3.9	4.7	8.3	8.1	25.0	49.2
Aomori	Standard	0.0	0.4	0.0	1.0	1.4	49.0
Nured Royal	Standard	2.2	4.8	4.6	7.2	18.7	45.9
Starkspur Ultrared	Spur	1.2	2.0	2.9	9.1	15.2	37.6
Average	Spur	4.1	6.8	10.1	13.0	34.8	61.5
	Standard	1.7	4.6	6.0	6.8	19.0	64.0
	All strains	3.0	5.8	8.8	10.3	28.0	62.6
LSD (5%)		0.5	0.8	3.0	1.4	4.3	13.3

leaf possibly due to the effects of cold injury to some fruit spurs.

The mean yield efficiency (kg fruit/ cm^2 trunk area) of strains (Table 2) ranged from 1.41 'Sturdeespur' to 0.71 'Classic Red.' The spur strains, with a mean of 1.17, were generally more efficient than the standard ones (mean of 0.86). The yield efficiencies of the trees when younger followed a similar pattern; in the seventh leaf all spur strains exceeded standard strains in efficiency (data not shown). In the sixth leaf 'Early Red One' exceeded the two spur strains 'Red King Oregon Spur' and 'Red Spur' but these younger trees had a yield efficiency of only 0.26.

The rating of estimated yield/ha ranged from 50.5 t to 21.6 t. Neverthe

Table 2. Yield efficiency, return bloom in ninth leaf, tree size and recommended density and estimated yield in eighth leaf.

Strain	Growth habit	Yield/ TCSA (cm^2)	Return bloom	Trunk CSA (cm^2)	Tree dia. (m)	Density trees/ha	Estimated yield tonnes/ha
Starking	Standard	0.92	37	90.5	4.75	364	30.2
Early Red One	Standard	1.09	26	75.1	4.00	470	38.5
Starkrimson	Spur	1.23	31	58.6	3.00	680	49.2
Red King Oregon Spur	Spur	1.19	42	59.5	3.00	680	48.1
Sharp Red	Standard	0.80	28	87.0	4.50	420	29.2
Wellspur	Spur	1.08	37	64.1	3.50	592	41.1
Ace	Spur	1.26	40	54.2	3.00	680	46.5
Redspur	Spur	1.26	41[z]	54.3	2.75	740[y]	50.5
Sturdeespur	Spur	1.41	19	48.1	2.75	740	50.3
Atwood	Spur	1.17	36	57.6	3.25	633	42.8
Imperial	Standard	0.97	32	69.4	4.00	470	31.5
August Red	Standard	0.86	25	77.0	4.25	494	32.7
Improved Ryan Spur	Spur	1.26	45	52.0	2.75	740	48.4
Classic Red	Standard	0.71	27	90.4	4.25	444	28.6
Hi-Early	Standard	0.82	23	77.7	4.25	494	31.5
Silver Spur	Spur	1.13	52	56.4	3.00	680	43.3
Rose Red	Standard	0.83	56	76.0	4.50	420	26.5
Apex	Spur	1.04	36	59.1	3.00	680	42.1
Topred	Standard	0.82	18	74.6	4.25	444	25.8
Starkspur Supreme	Spur	1.15	41	52.9	2.75	740	44.8
Hardi-Brite	Spur	1.25	45	43.4	2.50	909	49.2
Improved Ryanred	Standard	0.86	13	61.8	3.75	500	26.7
Redchief (Campbell)	Spur	1.19	28	44.4	2.75	740	39.4
Spured Royal	Spur	1.14	23	46.4	2.75	740	39.1
Hardispur	Spur	1.19	53	41.3	2.12	1,000	49.2
Aomori	Standard	0.80	28	61.0	4.00	470	23.0
Nured Royal	Standard	0.74	23	61.7	3.85	470	21.6
Starkspur Ultrared	Spur	0.81	48	46.5	2.25	1,000	37.6
Average	Spur	1.17	38.5	52.4	2.85	748	45.1
	Standard	0.85	28.0	75.2	4.20	455	28.8
	All strains	1.03	34.0	62.2	3.41	622	36.3
LSD (5%)		0.3		4.3	0.3		

[z]Rating from 1 to 100 (most bloom).
[y]Based on diameter plus 0.5 meter in the row plus 2 m alley.

The estimated yield generally paralleled the yield efficiency.

Fruit quality. Red color development of strains was indicated by the percent fruit in B.C. extra fancy the most colored classification (Table 3). Only two strains had more than 33% B.C. extra fancy fruit: 'Early Red One' (54.5%) a standard strain and 'Ace' (34.2%) a spur strain. 'Starking' had the least with no fruit in B.C. extra fancy. A group of nine spur strains were also poorly colored. The mean value for spur strains was 10.7% of fruit B.C. extra fancy compared to 16.0% for all standard strains.

The mean size of the fruit samples graded was relatively uniform but two strains, 'Red King Oregon Spur' (251.1g) and 'Aomori,' (263.8), were larger than the others. All other strains had mean fruit weights from 242g to 205g corresponding to 80 and 88 fruit per standard box.

Table 3. Fruit characteristics of 'Delicious' strains based on subsamples of 60 fruit (100 count) from the eighth leaf crop.

Strain	Growth habit	Average size (g)	Length / diameter	Seed No.	% B.C. extra fancy colour	Soluble solids %	SS/TA	Pressure (N)
Starking	Standard	215.2	0.99	5.6	0.0	14.9	35.1	68.7
Early Red One	Standard	241.4	0.97	6.2	54.5	14.5	34.6	66.6
Starkrimson	Spur	205.0	1.01	6.1	5.3	14.3	34.1	69.9
Red King Oregon Spur	Spur	251.1	1.00	6.3	21.6	14.6	33.7	62.6
Sharp Red	Standard	238.8	0.99	4.3	20.6	14.8	31.9	65.6
Wellspur	Spur	219.2	0.99	5.0	3.9	14.2	33.0	68.4
Ace	Spur	234.7	1.00	5.1	34.2	14.7	34.7	68.9
Redspur	Spur	214.0	1.00	4.6	2.0	14.8	33.3	70.2
Sturdeespur	Spur	212.6	1.00	5.7	4.2	14.1	36.2	62.1
Atwood	Spur	232.5	0.98	4.9	11.8	14.4	32.4	67.6
Imperial	Standard	210.5	0.98	4.5	9.9	14.2	31.7	70.5
August Red	Standard	234.2	0.95	4.3	12.6	14.5	34.1	68.0
Improved Ryan Spur	Spur	225.9	0.97	6.0	21.1	14.1	37.0	71.8
Classic Red	Standard	238.1	1.02	5.4	17.4	13.2	33.5	72.1
Hi-Early	Standard	234.1	0.98	5.2	12.3	14.8	34.9	70.6
Silver Spur	Spur	213.2	1.01	5.2	6.6	14.5	35.6	69.1
Rose Red	Standard	242.9	0.98	3.4	7.0	14.4	32.8	65.8
Apex	Spur	213.1	0.99	5.5	5.1	14.7	38.0	69.7
Topred	Standard	226.3	0.99	5.7	19.3	14.7	36.5	68.8
Starkspur Supreme	Spur	228.9	1.04	5.6	12.0	14.5	37.0	72.1
Hardi-Brite	Spur	220.9	0.96	5.1	6.2	15.0	38.5	70.0
Improved Ryanred	Standard	223.4	0.97	5.2	16.9	14.7	33.8	68.3
Redchief (Campbell)	Spur	226.5	1.01	4.5	15.7	14.1	37.6	70.3
Spured Royal	Spur	207.4	1.01	5.0	4.8	14.8	34.4	70.1
Hardispur	Spur	223.9	0.97	4.9	5.6	14.2	31.3	69.1
Aomori								
Nured Royal	Standard	241.3	0.99	3.9	14.3	14.8	32.0	71.9
Starkspur Ultrared								
Average	Spur	221.9	1.00	5.3	10.7	14.5	35.1	68.6
	Standard	234.2	0.98	4.9	16.0	14.5	33.7	68.8
	All strains	227.4	0.99	5.1	13.0	14.5	34.5	68.8
LSD (5%)			0.004	0.3				0.07

Strains were fairly consistent for percent unmarketable fruit with a mean of 9.1%. One strain, 'Nured Royal,' had 21.8% unmarketable fruit.

Fruit shape (L/D ratio) ranged from 1.04 'Starkspur Supreme' to 0.95 'August Red' with a mean for all strains of 0.99. Shape was not strongly associated with other traits. The mean of spur strains was 1.00 with standard strains 0.98. The mean seed number of all strains was 5.1 seeds per apple ranging from 6.3 'Red King Oregon Spur' to 3.4 'Rose Red.' The mean seed number of spur strains was 5.3 with the standard strains 4.9.

Mean °Brix was 14.5 with a range from 15.0 'Starking' to 13.2 'Classic Red.' Both spur and standard strains had a mean of 14.5. The sugar to acid ratio contributes to taste, with higher acid level desirable for 'Delicious' because it results in improved organoleptic quality after storage. It ranged from 31.3 to 38.5 with a mean of 34.5. The mean of all spur strains was 36.7 compared to 33.3 for the standards. Since the °Brix of the two growth types were equal, this difference reflects higher mean acid level in the spur strains.

Flesh firmness and color are two important determinants of quality when marketing fruit of 'Delicious.' The mean was 68.8 'Newtons' with no difference between spur and standard strains (Table 3).

Discussion

Although evaluations were made at only a single location, we consider them useful in assessing the strains for precocity and quality traits. Although interactions with environment might be expected, the strains are clones of a single cultivar and were evaluated in a location typical of northern 'Delicious' production areas. Information on many of these strains grown in other locations taken together with our results contribute to understanding environmental influences on 'Delicious' strain performance.

Tree size and production of M.7 EMLA and M.111 EMLA were similar in contrast to the observations of Ketchie (13). In his study, M.7 EMLA was more productive in the first four years. His trees had minimum pruning and training whereas ours were managed with trees on both rootstocks pruned similarly.

The precocity values of most of the spur strains exceeded the standard strains. 'Early Red One' was the most precocious standard strain. 'Starkspur Ultrared,' 'Redchief,' 'Hardispur,' 'Hardi-Brite' and 'Spured Royal' were amongst the smallest trees in the study, whether measured by tree diameter or trunk cross section area. The small tree size resulted in lower yields/tree than the best standard strain even though their efficiencies were similar to strains with higher yields/tree. The three standard strains with the highest precocity values were amongst the largest trees in the trial. Thus precocity values within each of the growth types were sometimes influenced by tree size, resulting in higher yields/tree even though efficiencies are similar. Warrington et al. (19) also found 'Early Red One' to have the highest yield and yield efficiency of the four year old trees in their trial. Our results confirm the precocity of this standard strain.

The yield efficiencies in the eighth leaf were clustered in two groups in a similar manner to the precocity values. The spur types had higher efficiencies, averaging 38% greater than standard strains. This was consistent in all years of the study and was also true for most spur and standard strains in Idaho (8).

At Summerland, the segregation of spur and standard strains based on efficiency was more distinct than in Michigan and West Virginia (19) and

Idaho (8). The most efficient standard strain exceeded six spur strains at West Virginia with similar overlap in Michigan. At Summerland only one did. In our study 'Starking' was the highest yielding strain while 'Starkrimson' was one of the most efficient: A similar result with these two strains was reported by Rom and Ferree (17) and Fallahi et al. (8).

The higher yield efficiency of the spur strains raises the question of overcropping which could result in biennial bearing (and low yield) the following year. Thus, return bloom in the ninth leaf was rated. The spur strains exceeded standard strains in bloom density. 'Sturdeespur,' the strain with the highest efficiency rating of 1.41, was the exception with a return bloom rating of 19 out of 100 compared to a mean of 39 for all spur strains and 28 for all standard strains. This shows that the highly yield high efficiency strains were not overcropped in their eighth leaf and similar efficiencies could be expected to be sustained; also fruit quality of the spur strains was representative and not reduced by excessive crop load in their eighth leaf.

The yields/tree in the eighth leaf were more homogenous than the efficiency or precocity ratings. The spur strain mean of 61.5 kg/tree was 2.5 kg less than the mean for the standard strains. The large tree size of the standard strains resulted in equal or higher yields even though their efficiencies were less.

Our purpose in evaluating these strains was, in part, to obtain data useful in predicting the relative value of the strains for commercial production. To this end, we estimated the yield/ha based on our observations of tree size and the efficiency of each strain using the calculation suggested by Warrington et al. (19). The result (Table 2) would benefit by confirmation with data from larger blocks and additional locations. It nonetheless contributes to indicating the potential of these strains in general. The predicted yield from the most productive strain was more than double that of the strain estimated to be least productive. The ranking, not surprisingly was related to tree efficiency and tree size with spur-types having higher predicted yields/ha than standard ones.

Highly colored fruit of large size are the most valuable and are preferred by consumers (5), however, the percentage of fruit in the most colored grade did not parallel the total yield of those strains. The strains highest in % B.C. extra fancy included both spur and standard types but nine spur types were poorly colored (Table 3). The low ranking of many spur strains may have resulted from the short internode characteristic of spur types and their greater leaf area per spur (19). This appeared to result in more shading near the stems of some fruit, which reduces color (16). Ketchie (13) also found that standard strains generally colored better than spur strains at Wenatchee, but the difference between types was not as great as at Summerland. In Idaho the differences were also smaller (8). An additional difference between the growth habit types was that fruit on spur type trees was at closer intervals (12) making mutual shading more likely.

Fruit size on spur strains with poor color was smaller than on the better colored spur strains. Their mean efficiency was 1.19 compared to 1.24 for the well colored spur strains, suggesting that coloring was not reduced by a different fruit:vegetative growth partitioning ratio. The fruiting spurs of the standard strains were longer than spur strains. This allowed the fruit to hang freely, away from the branch, resulting in less shading. The greater vegetative to fruit growth ratio of standard strains resulted in less color reduction than the higher density of spurs and the greater leaf area per spur of spur strains. The three well

colored spur strains had no apparent tree traits which distinguished them from the others. They may have a genetic pre-disposition to enhanced anthocyanin development.

Fruit size differences between strains were less than color differences. The two strains with the largest fruit size were 'Red King Oregon Spur' and 'Aomori.' 'Red King Oregon Spur' was the spur type with the largest tree based on trunk cross section area (59.5 cm^2) and had yield efficiency in the mid-range. This strain also had large fruit in Idaho (8). 'Aomori' was one of the smallest standard strains, with a trunk CSA similar to 'Red King Oregon Spur' (61.0 cm^2) with and a similar low yield efficiency of 0.80. Lord et al. (15) also found that 'Starkrimson' produced smaller fruit than standard strains in Massachusetts. Fallahi et al. (6), and Fallahi and Simonds (7) showed that size and color were both negatively correlated with crop load. This same general pattern was evident in our study. Barritt et al. (3) studied 'Red King Oregon Spur' and found that fruit size was positively correlated with greater sunlight levels but red skin color was not. The coloring of this strain (and possibly the more fully colored spurs in our study) was saturated at mid to low sunlight levels. Our results show that spur strains differ in their fruit size and coloring response since color and size were not influenced by the yield efficiency rankings.

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