bility analyses should prove useful to many breeders and horticulturalists who want to condense years of data into a few meaningful comparisons.

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Reviewed Research Paper

Color Evaluation of Seventeen Strains of 'Delicious'

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Introduction

Strain selection is a long term decision and can mean the difference between a profitable or unprofitable orchard. 'Delicious,' with over 100 different strains, provides the largest choice afforded commercial growers (4). In the selection process for new strains of 'Delicious' the primary criteria has been for improved or early coloring. In some areas, good red color can be a problem and local climatic differences can greatly affect its expression (1).

In the past, color evaluations of horticultural crops have largely been done on a visual basis (5). However, with increasing instrumentation it is now becoming more common to use automated colorimeters. Strachan (9) was among the earliest researchers to evaluate four red coloring limb sports in Canada. Dayton (3) in detailed anatomical studies reported differences between strains based on pigmentation characteristics in the epidermal cells of the fruit. Polesello and Gorini (8) further refined color determination by measuring twenty-six strains of Delicious with a Judd-Hunter color system. They broke the strains down into five groups based on lightness, hue, and saturation. While objective evaluations of color can eliminate variability and human bias, there is still a place for consumer acceptance panels (5, 6). The purpose then, of this work was to objectively and subjectively evaluate color and appearance of 17 strains of Delicious.

Materials and Methods

Ten fruit from each of the strains were harvested at 145 days after full bloom. All the strains were on M7 rootstock trained to a central leader system with annual pruning. The trees varied in age from 4 to 8 years and were growing in the variety block at the Georgia Mountain Experiment Station. Fruit color was evaluated using a Gardner XL-845 colorimeter adjusted with a pink standard (L =

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69.1, a = +23.4, b = +9.3). Measurements were performed on each of 10 apples at 8 points on the side circumference of each apple. Results were recorded as lightness (L), red/yellow ratio (a/b) and color difference ($\triangle$E) in accordance with the guidelines of Francis (6) and Francis and Clydesdale (5).

Subjective evaluations were conducted on four uniform apples by a panel of women. They were instructed to evaluate the samples solely on 'eye-appeal' as to whether they would purchase the apples in the store.

Results and Discussion

The L, a, b system places the average of the 8 readings of each apple in a 3-dimensional color space based on the color-opponent theory. The "L" value represents the lightness of the sample with a '0' indicating darkness and 100 lightness. A positive "a" value corresponds to the degree of redness while a negative value corresponds to greenness. A positive "b" value represents the degree of yellowness with a negative value representing blueness. A positive a/b ratio observed in most ripe "Delicious" apples is a ratio of the red-to-yellow character, with the higher the ratio the redder the fruit. The total color difference ($\triangle$E) represents the sum of the differences of L, a and b values of the sample and the standard. Since a pink standard was used, the greater the $\triangle$E the greater the color saturation of the sample.

'Dixie Red,' a newly introduced spur-type, produced fruit that was the darkest and had the most intense color (Table 1). 'Early Red One' was the highest rated non-spur in this study. Previous work (2) had also shown that

Table 1. Lightness (L), red/yellow ratio (a/b), and color difference ($\triangle$E) of selected 'Delicious' strains in 1983 at the Georgia Mountain Experiment Station.

Strain	L[z]	a/b[z]	$\triangle$E[z]
Dixie Red	20.3 a[y]	6.48 a	49.1 a
Early Red One	20.9 ab	6.43 a	48.4 ab
Grower Sport #2	21.7 ab	5.44 ab	47.5 ab
Grower Sport #1	22.7 bc	4.94 bc	46.5 bc
Ultrared	22.8 bcd	6.45 a	46.5 bc
Ace Spur	24.5 cde	3.88 def	44.7 cd
Oregon Spur	24.5 cde	3.34 defg	44.8 cd
Redchief	25.0 de	4.38 cd	44.0 d
Ryanred Spur	25.2 e	3.12 fgh	44.2 d
Prime Red	25.7 e	3.45 defg	43.4 d
Nured Royal	25.8 e	3.31 defgh	43.3 d
Topred	25.8 e	4.00 cde	43.2 d
Early Vance Spur	26.3 ef	3.19 efgh	42.7 d
Sharp Red	28.3 fg	2.93 efgh	40.7 e
Classic	28.9 g	2.55 gh	40.6 e
Chelan Red	29.0 g	2.79 fgh	39.8 e
Rose Red	29.7 g	2.64 gh	39.4 e
Redspur	30.0 g	2.21 h	39.2 e

[z]The greater the value the lighter the color (L), the more red than yellow (a/b) and the more intense ($\triangle$E) the color.
[y]Mean separation within columns, Duncans New Multiple Range Test, 5% level.

of a number of strains 'Early Red One' was the best coloring based on visual ratings. 'Ultrared' fruit was significantly lighter and less intensely colored than 'Dixie Red' but had a similar a/b ratio. Grower Sport #1 and #2 are unnamed limb sports of 'Oregon Spur' discovered by a Georgia apple grower. Both scored considerably better than some of the more commonly recognized strains.

Polesello and Gorini (8) in their work found seven strains that had lower L values than 'Dixie Red,' indicating darker coloring. The most notable of these were 'Ryanred' and 'Topred.' However, in their study all the strains had much lower a/b ratio's indicating a greater percentage of yellowish surface color.

As with previous studies (3, 8) it appears the strains can be classified into broad groupings with some overlapping based on color. 'Classic,' 'Chelan Red,' 'Rose Red,' and 'Redspur' were the least desirable strains in this study. 'Sharp Red' and 'Early Vance Spur' appeared to be transitional between the lowest group and the next highest. The second group would include 'Ryanred Spur,' 'Prime Red,' 'Nured Royal,' and 'Topred.' 'Ultrared,' 'Ace Spur,' and 'Oregon Spur' would be rated just slightly lower than the top three of 'Dixie Red,' 'Early Red One,' and Grower Sport #2. 'Redchief' and 'Grower Sport #1' also appear to be transitional between their respective groups. It is interesting to note that the three lightest colored strains are also those that have been in the commercial trade the longest (4).

The consumer panel rated 'Dixie Red' the highest followed by 'Ultrared' and 'Early Red One' (Table 2). 'Ryanred Spur' although lower in objective evaluation scored favorably in subjective ratings. This particular strain tends to be a brighter red and may explain its preference in the subjective ratings.

Table 2. Fruit 'eye-appeal' of selected strains of Delicious as evaluated in 1983.

Strain	Rating*
Dixie Red	4.8
Ultrared	4.5
Early Red One	4.4
Ryanred Spur	4.2
Grower Sport #2	4.1
Oregon Spur	3.7
Grower Sport #1	3.6
Ace Spur	3.6
Classic	3.5
Nured Royal	3.5
Sharp Red	3.5
Chelan Red	3.5
Topred	3.4
Rose Red	3.4
Early Vance Spur	3.2
LSD.01	0.2

*Subjective rating, with 5 being the most desirable and 1 the least desirable.

Comparisons between colorimeter results and consumer panels are beneficial, since instrument readings may not translate directly to understandable values (6). The use of consumer or objective evaluations help further define the interpretation of colorimeter readings. For example, in this study 'Ryanred Spur' did not rank as high on the subjective evaluations as on the objective tests. However, except for this one instance the results of the consumer panel closely followed the results of the colorimeter. The main advantage of the colorimeter is that it's readings can be reproduced consistently from year to year. The makeup of consumer panels can vary as can their likes and dislikes.

'Early Red One' and 'Dixie Red' trees produced the darkest most intensely colored fruit based on the results from both the subjective and objective tests. However, it is possible that in other areas these strains may color too darkly.

Other factors that should be considered in the selection of strains by growers are, ultimate tree size, growth

habit, efficiency, and anual production. Recent studies by Ketchie (7) have shown that there is a range in flowering and spurs per unit of branch length, that should be considered when selecting the strain to plant.

Conclusions

Color and earliness to color are strong determinants in selection of 'Delicious' strains by growers, but fruit maturity must not be overlooked. No attempt was made to measure maturity in this study and all strains were harvested at a predetermined time. Previous work has indicated a range of maturity among the various strains (2). Additional days on the tree may have increased fruit color; although 1983 was an average temperature year. However, for growers desiring to space out their Delicious harvest or harvest earlier then choosing one of the earlier coloring strains would be advantageous.

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I certify that the statements made by me are correct and complete. L. D. Tukey, Business Manager. October 4, 1984.