Changes in Condition and Color during the Late Development of Selected 'Delicious' Apple Strains

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Abstract. Firmness, total soluble solids (TSS), starch concentration (starch index, SINDEX), and surface color (L*, a*, and b*) were measured for 18 'Delicious' apple strains (*Malus × domestica* Borkh.) produced in a replicated, randomized planting at the West Virginia Univ. Experiment Farm, Kearneysville. There was a significant difference between 1991 and 1993 for firmness, L* on the blush or outer side (BL*), Bb*, BChroma, a* (nonblush side), hue angle, and Chroma. There were significant differences between strains in firmness and chromaticities and their derivatives, but not TSS or SINDEX. All measurements changed linearly with days after full bloom (DAFB). There were large chromaticity differences between the two sides of the fruit 130 DAFB, but the nonblush side changed more than the blush side, resulting in little difference at 158 DAFB. BL* (Ba*/Bb*) and L*(a*/b*) produced better separation of strains and sides than did Chroma, although the products were significantly correlated with hue angle and Chroma. The nonblush side of 'Delicious' fruits should be monitored to obtain the highest percentage of fruit in the highest grades.

'Delicious' is the most abundant apple cultivar in the United States, accounting for 44% of the 1994 crop (American Fruit Grower, 1994). Because of the large number of trees that have been planted in the last quarter-century, it will maintain its prominence for many years, despite the recent introduction of several new cultivars. While no precise count is possible, ~200 strains or budsports of 'Delicious' probably have been introduced over the last 50 years (Washington State Univ., 1969). Several attempts have been made to compare the late development or maturation and storage performance of strains. After collecting and evaluating fruit from several sites, we concluded that strains could be separated by soluble solids content (Ingle, 1972). A minimum level of soluble solids was suggested for satisfactory storage behavior (mainly superficial scald incidence), but the relationship was not tested by rigorous orthogonal analyses. Data from a subsequent study showed apparent differences in firmness, soluble solids, starch index, and internal ethylene among five strains (Ingle and D'Souza, 1989), but other studies showed none (Meheriuk, 1977;

Meheriuk and Porritt, 1971). None of these studies used fruit from replicated plots at the same site, so that rigorous comparisons were not really possible. For each strain, sufficiently high correlations between days after full bloom (DAFB) vs. firmness and superficial scald after refrigerated air storage were found to permit use of DAFB as a prediction tool (Ingle and D'Souza, 1989a).

In 1982 and 1983, a replicated, randomized planting of 45 'Delicious' strains was established at the West Virginia Univ. Kearneysville Experiment Farm. Some strains are now obsolete, or color poorly, or are otherwise of low commercial potential (Baughner et al., 1990). Eighteen strains that are in production or currently being planted were included in this study. In 1991 and 1993, fruits were sampled in order to compare their color, firmness, soluble solids, and starch index within one site.

Materials and Methods

Trees were planted in a north-south orientation in Hagerstown silt loam (Typic Hapudalts). Each block consisted of five trees of each strain and the two blocks were separated by a row of 'Golden Delicious' trees. Eighteen strains that were considered commercially significant were chosen for study. Strains were randomized within blocks. The trees were trained to a modified central leader, and commercial insecticides and fungicides were applied when determined necessary by monitoring.

Strains included in this study were Ace, Cascade Spur, Classic, DixieRed Spur, Improved Ryan Red, Oregon Spur, Oregon Spur II, Redchief (Campbell), Redchief (Mercier), Red Prince, Ryan Red Spur, Scarlet Spur, Silver Spur, Starkrimson, Sturdeespur, Topred, Triple Red, and Starkspur UltraRed. Names conform to propagators' catalogs.

In 1991, 10 fruits were collected from each tree on each of five dates; in 1993, 20 fruits were collected from each tree. These were pooled to give two samples of 20 or 40 fruits of each strain per block for each date. Five pickings were made at 7-d intervals, commencing 130 DAFB (29 Aug. 1991, 9 Sept. 1993). From each sample, 10 fruits were withdrawn randomly for at-harvest measurements.

Color measurements were made [on the reddest (blush) side and the opposite side of each fruit] with a Minolta 200B Chroma Meter (Minolta, Ramsey, N.J.) by placing the 8-mm-diameter measuring area on the apple surface midway between the stem and calyx ends. Chromaticity values were recorded in Commission Internationale d'Eclairage L*, a*, and b* color coordinates (Hunter, 1975). The meter was calibrated at illuminant C (6774 K) with a white standard before use. Firmness was measured with a Daytronic strain gauge, transducer, and data conditioner (Daytronic Corp., Miamisburg, Ohio). The system was calibrated against an Effegi penetrometer. Total soluble solids (TSS) were measured in juice collected during firmness measuring. A flesh starch index (SINDEX) was determined on horizontally sectioned fruits (Priest and Loughheed, 1981).

Strains and years were compared by analysis of variance (ANOVA), and harvest dates and regressions by the general linear model (SAS Institute, 1982).

Results

When data were averaged over strain and DAFB were combined, firmness, TSS, L* on the outer or blush side (BL*), Bb*, BChroma ($\sqrt{a^2 + b^2}$), L* (on the shaded side), a* hue angle ($\tan^{-1} b^*/a^*$), and Chroma differed significantly in 1991 vs. 1993 (Table 1). Main effects of strain for all fruit attributes measured except TSS and SINDEX differed significantly (Table 1). Starkrimson and Redchief (Campbell) were the firmest and UltraRed, DixieRed Spur, Ryan Red Spur, and Improved Ryan Red were the least firm (data not shown).

When data for years and strains were combined to determine the effect of maturity as measured by DAFB, firmness declined linearly with date of harvest. In 1993, all r^2 values for individual strains were greater than 0.70 ($P < 0.001$), except for Ace (data not shown). In 1991, firmness increased an average of 7 N between 130 and 137 DAFB and then declined, so that by 159 DAFB the mean firmness for all strains was 2 N less than at 130 DAFB. The changes were either quadratic (seven strains) or nonsignificant. In 1993, the firmness of all strains decreased linearly with DAFB ($P < 0.015$) and the r^2 on DAFB was >0.70 ($P < 0.001$) for each strain. The mean

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Table 1. Main effects of harvest time as days after full bloom (DAFB) and year on condition and color of 18 'Delicious' strains at harvest, Kearneysville, W. Va., 1991 and 1993.

Strain	Firmness (N)	Soluble solids (%)	Starch index	BL ^a	L ^a	Ba ^a	a ^a	Bb ^a	b ^a
Ace	82 bc ^y	12.3	3.5	40.3 d-f	51.9 f-h	26.0 a-d	18.3 ba	11.8 d-f	18.8 g-i
Cascade Spur	83 bc	11.8	3	43.2 bc	59.6 b	26.9 ab	8.8 f	13.4 bc	24.4 c
Classic	85 bc	13	3.2	42.6 bc	54.2 ef	25.9 a-d	17.9 b-d	13.0 b-d	20.1 e-g
DixieRed Spur	81 c	12.1	3.1	38.6 fg	50.8 h	25.2 b-e	20.4 b	10.3 gh	17.1 i
Improved Ryan Red	82 c	12.9	3.4	41.8 b-d	53.9 e-g	25.8 a-d	16.9 c-e	12.8 b-e	20.4 e-g
Oregon Spur	85 bc	12	3	43.1 bc	57.4 cd	25.1 c-e	11.2 f	13.4 cb	22.7 d
Oregon Spur II	85 bc	12.2	3.2	39.5 e-g	52.1 f-h	26.1 a-d	19.6 bc	11.4 fg	22.7 d
Redchief (Campbell)	90 a-c	12	3	39.9 d-f	52.4 f-h	27.0 a	18.3 bc	11.5 e-g	19.2 f-h
Redchief (Mercier)	86 a-c	13.1	3	38.9 e-g	50.9 h	26.6 a-d	19.4 bc	10.8 f-h	18.1 hi
Red Prince	88 ab	13.7	3.1	47.8 a	63.5 a	23.7 e	4.7 g	17.3 a	27.7 a
Ryan Red Spur	82 bc	12.3	3.3	41.1 c-e	54.0 e-g	25.0 c-e	15.1 de	12.1 c-f	20.7 ef
Scarlet Spur	86 bc	11.7	3.2	37.5 g	47.1 i	24.5 de	24.5 a	9.7 h	15.1 j
Silver Spur	85 ba	12.2	3.2	39.5 e-g	5.18 gh	25.4 b-d	15.7 bc	11.0 f-h	18.3 hi
Starkrimson	92 a	12.6	3.2	43.8 b	61.9 a	26.3 a-c	5.8 g	13.8 b	26.0 b
Sturdeespur	83 bc	12.1	3.2	43.2 bc	59.4 bc	26.3 a-c	9.5 f	13.9 b	24.7 bc
Topred	85 a-c	13.3	3.1	43.9 b	57.5 cb	26.0 a-d	14.2 e	13.7 b	22.4 d
Triple Red	84 bc	13.1	3.5	43.0 bc	55.7 de	26.4 a-c	17.4 b-d	13.6 b	21.5 e
Starkspur UltraRed	82 c	11.8	3.5	40.1 d-f	50.7 h	26.2 a-d	20.4 b	11.4 e-g	17.2 i
Year									
1991	87.2 b	13.4 b	3.2	42.5 b	55.6 b	5.8	14.0 a	12.0 a	20.5
1993	81.2 a	11.4 a	3.2	40.2 a	52.3 a	25.8	18.0 b	12.7 b	20.9
DAFB									
130	88.7	10.3	1.7	45.2	61.5	24.2	4.6	14.4	25.6
137	88.5	11.5	2.6	43.2	56.8	26.4	12.3	13.7	22.3
144	85	12.1	3	41	53.1	26.3	18.5	13	19.7
151	81	13.7	3.9	39.4	52.3	25.8	17.3	10.9	18.4
158	78	14.4	4.1	37.7	48.5	25.6	24.8	9.9	16.6
r ² for DAFB									
1991	0.534	0.747	0.922	0.861	0.871	0.645	0.887	0.828	0.884
1993	0.832	0.914	0.879	0.911	0.914	0.764	0.935	0.895	0.934
Interactions									
DAFB (L)	**	**	**	**	**	**	**	**	**
DAFB (Q)	**	*	**	**	**	**			
DAFB (L) × strain	**	**	**	**					
DAFB (Q) × strain									

^aB = Blush or reddest side of fruits.^yMean separation among strains, years, and r² values by Duncan's new multiple range test, $P \leq 0.05$.*, ** Interaction significant at $P \leq 0.05$ (*) or 0.01 (**), respectively.

firmness decrease over 28 d was 20 N (data not shown). Each strain had a unique rate of firmness change with slopes of the line relating firmness to DAFB ranging from 1.08 to 2.06. There were always small but significant differences between strains. The difference between the most and the least firm strains was 10–16 N. Starkrimson and Red Prince were usually the firmest strains, while Ace and DixieRed Spur were the least firm. TSS did not differ among strains when years and DAFB were combined, although at any date there were significant differences among strains. TSS rose from 9.0 to 13.3 (mean 11.7) at 130 DAFB in 1991, to 13.9 to 16.8 (mean 15.00) 158 DAFB. Regression line slopes ranged from 0.087 to 0.222. In 1993, the change was from 8.0 to 9.8 (mean 8.9) to 13.0 to 14.8 (mean 13.8) and the slopes were 0.145 to 0.225. The strains generally maintained their positions in high to low TSS rankings.

SINDEX was not affected by year or strain, and designation of strains as high or low SINDEX was not possible. In both years there were no differences between strains at 130 DAFB, and the rates of change were within a narrow range (slopes 0.107 to 0.158 in 1991, 0.062 to 0.128 in 1993). SINDEX started

lower in 1991 than in 1993, but increased more rapidly, so that it was a little higher 158 DAFB in 1991 than in 1993.

BL* changed linearly on all strains in both 1991 and 1993. Ace, DixieRed Spur, Oregon Spur, Redchief (Campbell), and Silver Spur also changed quadratically in 1993 (data not shown). Scarlet Spur, DixieRed Spur, and Silver Spur consistently had the lowest BL* values, while Red Prince had the highest BL* and L* values (Table 1). L* changed more rapidly than BL* (slopes 0.336 and 0.332, vs. 0.365 and 0.521, in 1991 and 1993, respectively, $P < 0.35$) (Table 2). The differences between the two sides changed from 17.4 (130 DAFB) to 12.4 (158 DAFB).

Ba* changed only 1.82 in 1991 and 1.29 in 1993 between 130 and 158 DAFB (data not shown). Slopes were -0.133 to -0.419. The r² was significant ($P < 0.05$) for only 50% of the strains. Differences among the strains were small but significant (Table 1). Values for Red Prince were consistently much lower than for other strains. Between 130 and 158 DAFB a* increased 19.0 in 1991 and 21.5 in 1993. Slopes for the 2 years averaged 0.625 and 0.784. The r² values for all strains were significant ($P < 0.01$). For 16 out of the 36 year-strain

combinations in 1991 and 1993, the a* became equal to or greater than the Ba*, as the fruits became uniformly red. In some cases Ba* decreased slightly, indicating a loss of red or "bleaching."

Bb* and b* decreased linearly as a function of DAFB in all strains in both 1991 and 1993. Scarlet Spur, DixieRed Spur, and Redchief (Mercier) had the lowest b* values while Red Prince, Starkrimson, Sturdeespur, and Cascade Spur had the highest b* values (most yellow). All the slopes were negative and all r² values were significant. Although the slopes for b* were higher than for Bb*, they were not large (<0.367).

Most of the changes in BChroma and Chroma within strains were erratic and were neither linear nor quadratic (data not shown). However, the change was significant when years and strains were combined (Table 2). Changes in color differed among strains, since slopes ranged from negative to positive.

Bhue angle was nearly the same in 1991 and 1993 (Table 2), but hue angle was significantly higher in 1991 (data not shown). Both changed significantly with DAFB in both years in all but two strains. There were significant differences among strains in both years. Strains

Table 2. Effect of strain of 'Delicious' on (L*) (a*/b*) on the blushed (B) and nonblushed sides of apple fruits, Kearneysville, W.Va. Mean values for all harvests in 1991 and 1993.

Strain	BL* (Ba*/Bb*) ^a	L* (a*/b*)	Blue angle	Hue angle	BChroma	Chroma
Ace	90.1 a-f	53.1 b-d	24.1 d-g	46.7 g-j	28.6 c-f	28.7 d-f
Cascade	88.4 a-f	25.5 b	26.7 bd	68.7 bc	30.3 a	30.1 ac
Classic	86.6 c-f	51.7 c-e	26.2 b-e	48.8 f-i	29.1 a-e	28.9 d-f
DixieRed Spur	96.0 a	61.0 b	21.6 g	42.1 ij	27.3 fg	27.9 f
Improved Ryan Red	86.8 c-f	48.1 de	26.2 b-e	50.4 f-h	29.1 a-e	29.0 c-f
Oregon Spur	82.8 f	31.3 g	28.0 b	65.5 cd	28.8 b-e	28.0 ef
Oregon Spur II	92.0 a-c	55.4 b-d	23.2 d-g	45.2 g-j	28.4 d-f	29.0 c-e
Red Prince	67.6 g	13.2 i	36.4 a	77.5 a	30.3 a	30.7 ab
Redchief (Mercier)	95.4 ab	57.7 b-d	22.2 fg	43.9 h-j	28.1 ef	28.8 d-f
Redchief (Campbell)	95.1 a-c	52.2 b-d	23.0 e-g	48.1 g-j	29.5 a-d	29.1 c-e
Ryan Red Spur	87.2 b-f	41.3 ef	25.3 b-f	53.7 ef	27.9 ef	28.1 ef
Scarlet Spur	96.7 a	78.3 a	20.9 g	32.2 k	26.3 g	29.6 b-d
Silver Spur	93.2 a-d	54.9 b-d	23.0 e-g	45.7 g-j	27.8 ef	28.2 ef
Starkrimson	86.5 d-f	18.4 hi	27.8 b	73.4 ab	30.2 a	30.9 a
Sturdeespur	84.2 f	26.8 gh	27.8 b	67.2 bc	30.1 ab	30.6 ab
Topred	83.2 f	37.7 f	27.7 b	57.2 de	29.8 a-d	29.5 cd
Triple Red	85.8 d-f	49.0 ed	27.0 bc	51.0 d-f	30.0 a-c	29.8 b-d
Starkspur UltraRed	94.2 a-d	62.7 b	23.3 d-g	41.4 j	28.7 c-e	28.4 ef
DAFB ^a						
130	78.07	13.02	31.2	75.8	28.5	28.7
137	84.17	33.38	27.6	60.7	30	28.3
144	91.24	50.59	25	47.9	30	29.3
151	94.62	58.39	22.6	44.1	28	28.9
158	98.31	73.27	20.8	35.5	27.5	30.9
Year						
1991	93.4 a	42.3	25	56.1 a	28.7 a	28.3 a
1993	83.6 b	48.6	26	49.2 b	29.0 b	30.0 b
r ² for DAFB						
1991	0.917	0.954	0.797	0.891	0.688	0.748
1993	0.92	0.971	0.905	0.943	0.759	0.741
Interactions						
DAFB (L)	**	**	**	**	**	**
DAFB (Q)	**	**	**	**	**	**
DAFB (L) × strain	**	**	**	**	**	**
DAFB (Q) × strain	**					

^aB = blush or reddest side of fruits.

^bMean separation among strains, years, and r² values by Duncan's new multiple range test at P ≤ 0.05.

^cDAFB = days after full bloom.

^d**Interaction significant at P ≤ 0.05 (*) or 0.01 (**), respectively. L = linear; Q = quadratic.

with the highest Blue angle at the first harvest changed most rapidly but still had the highest values 4 weeks later (data not shown).

Discussion

Most of the fruit characteristics measured changed linearly with time after the first harvest, which was at least 10 d prior to that recommended for growers in the West Virginia area (Haller and Smith, 1950). The increase in firmness between 130 and 137 DAFB in 1991 has been reported before (Ingle, 1972; Ingle and D'Souza, 1989a), but the reason for this is not known. There were 21.5 mm of rainfall 136 DAFB just before the second collection in 1991, but other significant precipitation occurred within the time frame of the experiments that were not followed by firmness increases.

In situ measurements indicated that several strains of 'Delicious' from the same block reached maximum coloration on the blush side by the first week in September (Singha et al., 1989). Although coloration was not defined explicitly, it appears to have involved some combination of L*, a*, and b*. In this experiment, BL*, Ba*, and Bb* changed very little

after 130 DAFB, which was on 29 Aug. 1991 or 9 Sept. 1993. Probably because of the large number of strains and collections, ANOVA showed a small but significant difference among collections (Table 1); however, chromaticity changes on the blushed side showed no trend or pattern. The rates of change in BL*, Ba*, a*, b*, and their derivatives, Blue angle, hue angle, BChroma, Chroma, BL*(Ba*/Bb*), and L*(a*/b*), were different for each strain and year (Tables 1, 2). L*, a*, and b* increased considerably and the increases were linear. The difference in a* between the two sides decreased from 17.4 (130 DAFB) to 1.9 (158 DAFB) in 1991 and from 20.5 to 3.2 in 1993, which should indicate a more uniform redness. Comparison of strains and changes with time would be facilitated by a term that would combine L*, a*, and b*. L* and some combination of a* and b*, such as hue angle or Chroma, might be reported when attempting to describe commodity color (Francis, 1980; McGuire, 1992). A number of chromaticity values correlated reasonably well with visual color ratings (Singha et al., 1991b). The regressions for L* and a*/b* were among the best. The products of L* and a*/b* [BL*(a*/b*) or L*(a*/b*)] seem to reflect the

combined and interrelated effects of the three chromaticities. When strains and years were combined, the product on the blush side changed from 77.93 to 98.18 between 130 and 158 DAFB. The ranking of strains by L*(a*/b*) was essentially the same for both sides of the fruits. The r² for the visual ratings vs. BL*(a*/b*) was 0.69; for visual ratings vs. a*/b*, it was 0.80 (data of Singha et al., 1991b). The advantage of L*(a*/b*) is that the strain differences among harvest dates and fruit sides are more clearly separated than with Chroma. Hue angle and L*(a*/b*) ranked and separated the strains similarly, particularly on the nonblush side (Tables 1, 2, 3) and there was a high correlation between hue angle and the L*(a*/b*) products (r² = 0.97 on the blush side, 0.99 on the nonblush side, P < 0.001). Correlations with Chroma were considerably lower, but still significant (P < 0.003). For all strains L*(a*/b*) changed from 19.8 to 79.2, while BL*(Ba*/Bb*) changed from 77.9 to 98.2. Scarlet Spur, which was rated by a panel to be highly colored (Singha et al., 1991b), had a mean for all DAFB products on the blush side of 96.7, while less well-colored strains, such as Red Prince and Starkrimson, were rated 67–86 (Table 2). On the nonblush side, Scarlet

Table 3. Main effects of sampling date over 1991 and 1993 on chromaticity of Starkrimson and Scarlet Spur 'Delicious' on blushed (B) and nonblushed sides, Kearneysville, W.Va.

Chromaticity	Sampling time (DAFB ²)									
	130		137		144		151		158	
	Stain		Stain		Stain		Stain		Stain	
	Sk ³	Ss	Sk	Ss	Sk	Ss	Sk	Ss	Sk	Ss
BL*	48.4 a*	38.9 b	47.4 a	38.8 b	43.5 a	37.7 b	41.4 a	36.1 b	37.0 a	34.6 b
L*	70.8 a	52.0 b	67.0 a	47.7 b	59.0 a	45.6 b	59.3 a	45.7 b	52.1 a	42.6 b
Ba*	22.8 a	15.3 b	26.0 a	36.4 b	28.7 a	35.3 b	27.3 a	23.6 b	27.2 a	21.5 b
a*	-10.6 b	17.7 a	-1.8 b	23.6 b	11.1 b	27.1 a	11.4 b	26.5 a	21.9 b	28.4 a
Bb*	16.6 a	10.7 b	15.3 a	10.7 b	14.4 a	10.4 b	11.9 a	8.3 b	9.8 a	7.4 b
b*	33.6 a	17.3 b	29.6 a	15.0 b	23.9 a	15.3 b	23.0 a	14.0 b	18.6 a	12.6 b
BChroma*	29.0 a	27.5 b	30.4 a	28.5 b	32.3 a	27.5 b	29.9 a	24.1 b	28.9 a	23.0 b
Chroma*	35.8	28.8	31	28.7	29.5	31.8	28.5	30.3	30	36.2
Bhue angle*	37.1	22.3 b	32.0 a	25.3 b	26.9	21.9	23.3	19.7	19.7	18.6
hue angle*	105.8 a	43.1 b	91.1 a	33.0 b	65.6 a	31.8 b	63.0 a	38.3 b	41.8 a	31.2 b
Ba*/Bb*	1.4	2.1	1.7	2.1	2	2.4	2.3	2.6	2.9	2.8
a*/b*	-0.3	-0.5	-0.1	-0.8	0.5	1.1	0.6	1.4	1.2	1.7
BL* (Ba*/Bb*)	66.9 b	95.1 a	79.4 b	96.0 a	86.8 b	92.2 a	96.7 b	98.3 a	103.0 b	102.0 a
L* (a*/b*)	-22.4 b	58.0 a	-4.1 b	74.2 a	26.8 b	80.8 a	30.6 b	86.3 a	61.3 b	96.6 a

²DAFB = days after full bloom.³Sk = Starkrimson; Ss = Scarlet Spur.⁴Mean separation between strains within sampling times and chromaticity parameters by Duncan's new multiple range test, $P \leq 0.05$.

Spur had a mean of 78.3 vs. 13.2 for Starkrimson; however, the change on the nonblush side was much greater than on the blush side, so that there was a constant decrease in the difference between the two sides, particularly for Starkrimson (Table 3). BL*(Ba*/Bb*) changed linearly with DAFB ($P < 0.001$). On the nonblush side the change was mainly linear, but there was a slight decrease in the rate of change between 144 and 155 DAFB, followed by a return to the original rate. This decrease remains unexplained. Visual evaluation indicated an increased color up to at least 3 Oct. in most of the 'Delicious' strains evaluated in Michigan (Dennis, 1989). By 158 DAFB, differences among strains in chromaticity on the blush side, especially L*, a*, b*, and L*(a*/b*) between strains, had become very small. Red Prince, Starkrimson, and Sturdeespur had low values on the nonblush side 130 DAFB, and although they changed more than Scarlet Spur over the next 28 d, there were still considerable differences between the two sides in comparison with Scarlet Spur.

'Delicious' and other red apple cultivars are graded by the amount of surface that is colored red (Smith and Frye, 1964; U.S. Dept. of Agriculture, 1972). Because the nonblush side continues to develop redness and brightness until abscission (155–160 DAFB in West Virginia), maximum harvest delay seems reasonable. The nonblush side of the fruit therefore should be monitored. As DAFB increases, softness after storage will be reduced (Ingle and D'Souza, 1989). However, incidence and severity of storage scald usually decreases (Anet, 1972; Blanpied et al., 1991; Bramlage

and Watkins, 1994; Ingle and D'Souza, 1989b), and storage temperature management becomes more critical to minimize softening.

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