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Southern Highbush Blueberry Clones Differ in Postharvest Fruit Quality

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Abstract

Fruit from genotypes of southern highbush blueberries (*Vaccinium* spp.), and 'Sierra' were compared for postharvest quality. Commercially important rabbiteye (cv. Climax) and northern highbush (cv. Bluecrop) were included as standards. 'Gulfcoast,' 'Cooper' and 'Cape Fear' fruit retained 10-20% of pedicels after harvest ('stemming') while very few pedicels were retained on other cultivars. Fruit from the selection G616 were greatest in weight (2.8g) and 'Cooper' the smallest (1.7g). A109 fruit had the smallest stem scar and MS108 the largest. 'Sierra' and 'Climax' fruit had the least decay among all clones. G616 fruit were the least firm of all clones after storage. Soluble solid concentration/titratable acidity ratios were between 10 and 19 for all clones. Anthocyanin content was highest in 'Cape Fear' and lowest in MS108. Of the new southern highbush clones, 'O'Neal,' G616 and A109 cultivars were equal to or better than 'Bluecrop' or 'Climax' in postharvest quality and shelf life.

The storage life of rabbiteye (*Vaccinium ashei* Reade) and northern highbush (*Vaccinium corymbosum* L.) blueberries has been studied extensively (1, 2, 3, 5, 9, 10, 11, 17). The southern highbush blueberry (*Vaccinium* spp.) is a hybrid derived largely from *V. corymbosum* and *V. darrowi* Camp. parentage and has a low chilling requirement and earlier ripening date than rabbiteye cultivars (8). Acreage planted in southern highbush blueberries is predicted to expand greatly by the year 2000 (13).

The storage life of rabbiteye blueberry fruit is reported to be superior to that of northern highbush fruit due to less fungal decay (10). However, only a few southern highbush blueberry cultivars have been studied for fruit quality. Miller et al. (12) found that southern highbush 'Sharpblue' fruit softened more rapidly than 'Climax' rabbiteye fruit during storage. Lang and Tao (7) reported that stored southern highbush fruit from 'Gulfcoast' was of lower quality than 'Sharpblue.' Although 'Sharpblue' acreage is currently the largest in the world, this cultivar has stem scar tearing, and corolla and pedicel adhesion, making

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it a poor quality cultivar in areas where early markets cannot be obtained.

With the predicted expansion of southern highbush blueberry plantings, evaluation of the storage life of southern highbush germplasm is important. The purpose of this experiment was to evaluate the shelf life quality of 'Sierra' and seven southern highbush cultivars and breeding selections and compare these with a commercially important rabbiteye and northern highbush cultivar.

Materials and Methods

Blueberry fruit were harvested from the southern highbush cultivars 'Cape Fear,' 'Cooper,' 'Gulfcoast,' 'O'Neal,' and the breeding selections MS108, A109, G616. 'Sierra,' which was released as a northern highbush cultivar, but includes several southern *Vaccinium* spp. in its parentage, was also harvested. 'Climax,' a rabbiteye, and 'Bluecrop,' a northern highbush cultivar were used as standards. 'Sharpblue' does not consistently fruit outside the deep south and was not used in this experiment. Established plants used for harvests were not sprayed with fungicides from bloom through fruit ripening and were grown at the University of Arkansas Clarksville Fruit Substation, Clarksville, Ark. Bushes were harvested when at least 30% of fruit were ripe. Because of the short (2-4 weeks) fruiting season at this location, each clone was harvested twice at weekly intervals and results averaged for the harvest dates.

Harvested fruit, consisting of three to four liters per clone, were held in pulp boxes at 7-10C and transported to Lane, Okla. within 5 hours of harvest. Fruit were sorted to eliminate overripe, injured or immature berries. A total of 6 replicates, three per harvest date, were used for each clone. A replicate consisted of two 250 ml pulp boxes, each containing 40 fruit. Each box was covered with a cellulose acetate wrap. Fruit were held at 5C, 90% RH for 21 days then held one day at 20C, 80% RH to test fruit response under simulated transit and retail conditions.

A total of 40 fruit per clone were weighed individually to determine berry size, and stem scar diameter at widest point was measured to 0.01 mm using a dissecting microscope before storage. Fruit epidermal firmness was measured at three equatorial sites per berry using a gram gauge penetrometer adapted with a 0.3 mm wire (14) on 40-berry subsamples taken before and after storage for each cultivar. Stem end firmness via wire penetration was measured once at the berry stem scar. A mean of epidermal and stem scar firmness measurements was used to gauge the total berry firmness. Fruit were rated for pedicel adherence ('stemming') prior to storage and for the presence and severity of fungal decay after storage, where 1 = no decay and 9 = 80-100% decay. Weight loss was determined after storage at 5C and 20C.

Fruit composition, consisting of percent soluble solids concentration (SSC), titratable acidity (TA), and total anthocyanin content, was determined using frozen fruit. A total of four replicates, 20 g per replicate, were homogenized with a Waring Blendor. Five g of fruit puree was extracted twice with acidified ethanol and absorbance at 543 nm of combined supernatants was read on a Shimadzu UV-160 spectrophotometer (Shimadzu Scientific Instruments, Columbia, MD 21046). Ten g puree was combined with 90 ml deionized distilled water, pH measured, and acidity determined by titrating to a final pH of 8.2 using 0.1 N NaOH and expressed as percentage citric acid on a fresh weight basis. SSC was determined from the remaining puree using an Atago PR-100 digital refractometer (NSG Precision Cells, Inc., Farmingdale, NY).

Results were analyzed using ANOVA (general linear means model). The interaction of storage and clone was significant for all variables measured. Interaction means were separated within the main effects of clone by LSD, P ≤ 0.05, and between storage days by t-test, P ≤ 0.05.

Results and Discussion

Ten to 20% of 'Gulfcoast,' 'Cooper,' 'Cape Fear' and MS108 fruit had attached pedicels in the fruit pack prior to sorting (data not shown). This tendency to retain fruit pedicels, known as stemming, is a negative attribute associated with stem end tearing on the fruit, and can result in a lower fruit pack grade (18). Stem scar tearing has been reported to occur for 'Gulfcoast' (7), but little tearing was observed on any fruit in our study.

The southern highbush blueberries in this study displayed a high degree of variability in fruit weight and stem scar size among the cultivars and selections, similar to that reported for rabbiteye and northern highbush fruit (10). Clones varied widely in fruit weight, from 2.80 g for G616 fruit to 1.72 g for 'Cooper' fruit (Table 1). Fruit weights for 'Climax' and 'Bluecrop' were 18% less than those reported by Makus and Morris (10). This difference may have resulted from seasonal and environmental variability between production sites. Stem scar size varied as much as 50% among clones (Table 1). Large fruit did not necessarily have large stem scar diameters. To more easily compare fruit weights and stem scar diameters among clones, a ratio stem scar diameter to berry weight was calculated, where a smaller value was more desirable than a larger value. Using this ratio G616 fruit were highest and MS108, 'Gulfcoast' and 'Cooper' were lowest among clones.

After 21 days storage at 5C. 'Sierra.' G616, and A109 fruit had the least % weight loss and 'Gulfcoast' and 'Climax' the most (Table 1). Differences in total weight loss were less clear. 'Gulfcoast' had the most total weight loss among all clones. Except for 'Gulfcoast,' total weight loss among the southern highbush lines was similar to or less than that of 'Bluecrop' or 'Climax.'

Decay incidence was slight on 'Sierra' and 'Climax' fruit (Table 1). Most of the southern highbush clones had 20-30% decayed fruit, which was comparable to that of 'Bluecrop.' For all clones, decay usually occurred on the

Table 1. Characteristics of blueberry fruit following harvest and after 21 days storage at 5C and 1 day at 20C.[z]

Clone	Initial measurements: Fruit[x] weight (g/berry	Stem scar diam. (mm)	Stem scar/wt	After storage: Weight[y] loss at 5C (%)	Total[y] weight loss (%)	Decayed[w] fruit (%)
A109	2.19b	1.46a	0.67b	3.6a	6.3a	7.4ab
Cape Fear	1.95cd	1.77b	0.91d	4.9b	8.8cd	20.1bcd
Cooper	1.72e	2.11cd	1.23e	6.0c	10.9e	31.3de
Gulfcoast	1.90cd	2.06c	1.08e	6.6d	12.1f	34.0ef
G616	2.80a	1.74b	0.62a	3.7a	7.0ab	20.9cde
MS108	1.82de	2.20d	1.21e	5.1b	9.5d	36.0f
O'Neal	1.99cd	1.53a	0.77c	5.4b	9.7de	15.9bc
Sierra	1.84de	1.50a	0.82c	4.2a	7.8bc	0.5a
Bluecrop	2.00c	1.87bc	0.94d	5.9c	9.8de	29.2def
Climax	1.93cd	1.46a	0.76c	6.7d	10.8e	2.1a

[z]Means separated within columns by LSD, P ≤ 0.05.
[x]Values for fruit weight, diameter, and stem scar diameter represent means of 40 fruit per clone.
[y]Values for weight loss represent means of 6 boxes per clone. Total weight loss represents weight loss after 21 days storage at 5C plus one day storage at 20C.
[w]Values for fruit decay represent means of 200-250 fruit per clone.

Table 2. Blueberry fruit epidermal and stem scar firmness before and after 21 days storage at 5C plus one day at 20C.[z]

Clone	Epidermal firmness[x] Before storage (g/mm)	Epidermal firmness[x] After storage (g/mm)	Firmness change (%)	Stem scar firmness[y] Before storage (g/mm)	Stem scar firmness[y] After storage (g/mm)	Firmness change (%)	Average firmness[w] Before storage (g/mm)	Average firmness[w] After storage (g/mm)	Firmness change (%)
A109	59b	43b	27ab	41f	40bc	2c	50d	42b	17b
Cape Fear	61b	49a	20b	60ab	51a	15bc	61b	50a	17b
Cooper	61b	41bc	33ab	55c	45b	18ab	58bc	43b	26ab
Gulfcoast	68a	48a	29ab	64a	52a	19ab	66a	50a	24ab
G616	51c	37c	27ab	47de	36c	23ab	49d	37c	26ab
MS108	59b	49a	17b	59bc	52a	12bc	59bc	51a	14b
O'Neal	67a	44b	34a	64a	44b	31a	66a	44b	33a
Sierra	58b	49a	16b	55c	49a	11bc	57c	49a	13b
Bluecrop	51c	43b	16b	48d	43b	10bc	50d	43b	13b
Climax	58b	44b	24b	43ef	44b	-2c	51d	44b	13b

[z]The interaction of storage day x clone was significant at $P \leq 0.05$ for all variables except stem scar firmness. Differences between storage days were significant for all cultivars except 'Climax' and A109 stem scar firmness. Means separated within columns by LSD, $P \leq 0.05$.
[x]Values represent means of 3 readings per fruit; 40 fruit per clone.
[y]Values represent means of 1 reading per fruit; 40 fruit per clone.
[w]Average firmness represents the average of mean values for stem scar and epidermal firmness.

stem end and covered 10-20% of berry surface area (data not shown).

Fruit firmness at harvest was not a good indicator of firmness after storage. For example, 'O'Neal' had high epidermal and stem scar firmness before storage but was intermediate to low in firmness after storage compared to the other clones (Table 2). For all clones, fruit epidermal firmness decreased following storage. Except for 'Climax' and A109, all clones had decreased firmness at the stem scar following storage.

When stem scar and epidermal firmness were averaged, the southern high-

Table 3. Changes in blueberry fruit composition after 21 days storage at 5C followed by 1 day at 20C.[z]

Clone	Soluble solids concentration Before storage (%)	Soluble solids concentration After storage (%)	Titratable acidity Before storage (% citric acid)	Titratable acidity After storage (% citric acid)	SSC/TA Before storage	SSC/TA After storage	pH Before storage	pH After storage	Total anthocyanin Before storage (Abs. units/g fw)	Total anthocyanin After storage (Abs. units/g fw)
A109	11.5a	10.9b	1.13a	0.98b	10.2b	11.1de	3.16c	3.25f	108c	119c
Cape Fear	10.1a	10.2bc	0.54d	0.63fg	18.7ab	16.2c	3.43a	3.40cd	142b	228a*
Cooper	9.5b	9.4c	0.68cd	0.96bc*	14.0ab	9.8e	3.33ab	3.28ef	98cd	112c
Gulfcoast	9.6b	9.9bc	0.75bcd	0.86cd	12.8b	11.5de	3.32ab	3.37de	111c	91c
G616	10.3ab	11.2b	0.95abc	0.67ef*	10.8b	16.7c	3.25b	3.47bc*	94cd	96c
MS108	10.4ab	11.0b	1.02ab	1.18a	10.2b	9.3e	3.01d	3.12g*	57e	66d
O'Neal	11.1a	11.0b	0.69cd	0.48h*	16.0ab	22.9b*	3.32ab	3.66a*	106c	160b*
Sierra	10.0ab	10.7bc	0.97abc	0.77de	10.3b	13.9cd	3.14c	3.43bcd*	111c	142b*
Bluecrop	9.0b	10.0bc	0.82abc	0.76de	11.0b	13.2d	3.39a	3.51b*	83de	90c
Climax	10.9a	13.6a*	0.56d	0.52gh	19.5a	26.2a*	3.38a	3.46bcd	208a	226a

[z]Values represent means of 6 replicates, consisting of 20g fruit puree per replicate. The interaction of storage day x clone was significant for all variables at $P \leq 0.05$. Means separated within columns by LSD, $P \leq 0.05$.
*Means separated between storage days by t-test, $P \leq 0.05$.

Table 4. Summary of postharvest blueberry fruit quality.[z]

Clone	Stemming	Weight stem/scar	Total weight loss	% Decay	Average firmness after storage	% Change in average firmness	SSC/TA	Rank Sum
A109	1	2	1	2	2	1	3	12
Cape Fear	2	3	4	3	1	1	2	16
Cooper	2	4	8	4	2	2	2	24
Gulfcoast	2	4	9	7	1	2	3	28
G616	1	1	2	5	3	2	3	17
MS108	2	4	5	8	1	1	3	23
O'Neal	1	3	6	3	2	3	2	20
Sierra	1	3	3	1	1	1	3	13
Bluecrop	1	3	6	6	2	1	3	22
Climax	1	2	7	1	2	1	1	15

[z]Total score determined by multiplying all variables across columns. Scores within columns based on mean value rankings from Tables 1-3. Lower scores indicate better fruit quality.

bush clones 'Cape Fear,' 'Gulfcoast' and MS108 were higher in firmness than 'Bluecrop' and 'Climax' after storage (Table 2). G616 fruit were of similar firmness to 'Bluecrop' and 'Climax' before storage but were the softest fruit of all clones after storage. The percent change in average firmness was low for A109, 'Cape Fear'; MS108, 'Sierra,' 'Climax,' and 'Bluecrop' fruit. Miller et al. (12) rated 'Climax' fruit much firmer than fruit of the southern highbush cultivar 'Sharpblue' after storage. Basiouny and Chen (2) theorized that firmness of rabbiteye fruit increased because of shrinkage from weight loss. While data from another season or location are needed to distinguish environmental effects from genetic variation, our results indicate that several southern highbush clones can maintain firmness during storage.

Percent SSC did not differ greatly among clones and did not significantly differ between stored and fresh fruit, except for 'Climax,' which increased considerably in SSC after storage (Table 3). Although weight loss can concentrate sugars, the weight loss of 'Climax' fruit was less than that of 'Gulfcoast,' which showed no change in SSC.

Titratable acidity ranged from 0.54 to 1.13% among clones (Table 3). After storage, G616 and 'O'Neal' were significantly lower and 'Cooper' was higher in titratable acidity. Initially, most of the southern highbush fruit, excluding 'Cape Fear,' had an SSC/TA ratio of less than 18, which is recommended for longest storage life (4). The high SSC/TA value found for 'Climax' fruit is similar to other values reported for this cultivar (10, 17). Both 'Climax' and 'O'Neal' fruit had a SSC/TA ratio higher than 18 following storage.

All pH values found for fruit in this study were within the range recommended for optimum shelflife (<3.50) and similar to those reported for ripe but not overripe fruit (3.00-3.50) (1, 6). 'MS108' fruit had an unusually low pH compared to the other clones; fruit appeared to be at the same ripeness stage as those of other cultivars at harvest (Table 3). Following storage, the fruit pH of five cultivars increased significantly. Basiouny and Chen (2) reported a slight increase in pH for blueberries after 30 days storage at 5C, without a change in titratable acidity.

Initially, anthocyanin content of 'Climax' fruit was considerably higher compared to the other clones (Table 3). The anthocyanin content of 'Bluecrop' fruit was similar to that reported by Sapers et al. (15). Among the southern highbush clones, 'Cape Fear' fruit were highest in anthocyanin content. After storage, 'Cape Fear' and 'O'Neal' had a 55% increase in anthocyanin content and 'Sierra' increased by 22%. Blueberry fruit have been reported to increase in anthocyanin content as much as 25% during storage (2, 16).

To quantitatively distinguish postharvest quality among blueberry clones, a summary table was developed (Table 4). Attributes considered most important in determining USDA grade and market preference were selected from data. Clones were ranked in each category based on mean value separations from Tables 1 through 3 and numbers summed to achieve a final score. Based on this scoring method, 'Sierra' and A109 fruit were similar to 'Climax.' 'Cooper,' 'Gulfcoast' and MS108 had high (less desirable) scores that exceeded that of 'Bluecrop.' Therefore, two southern highbush clones were ranked similar to 'Climax' in having excellent postharvest quality while four southern highbush clones and 'Sierra' had fruit equal to or better than 'Bluecrop' fruit following storage.

Summary

Storage quality, consisting of berry size, firmness, decay, weight loss, anthocyanin, SSC and titratable acidity, was evaluated for blueberry clones. Of these, 'Cape Fear,' 'Sierra,' G616 and A109, were comparable in quality to 'Bluecrop' and 'Climax,' each a commercially important northern and rabbiteye highbush cultivar, respectively. Of the cultivars and breeding selections used in this study, 'Cooper,' 'Gulfcoast,' and MS108 fruit were lowest in postharvest quality. Additional data will help determine the yearly variability in the storage quality of these southern highbush clones. Productivity aspects and environmental conditions, combined with a general knowledge of postharvest quality, should aid researchers and growers in selection of southern highbush cultivars for new plantings.

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Cold Hardiness in *Rubus*[1]

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Abstract

More than 80 raspberry and 42 blackberry genotypes were evaluated for cold hardiness after controlled laboratory freezing in January 1990. Red, yellow, black, and purple raspberry cultivars (*R. idaeus* L., *R. neglectus* Peck), blackberry cultivars (*R. allegheniensis* Porter, *R. ursinus* Cham & Schldl.) and other *Rubus* species selections were examined. T_{50}'s, the temperatures where 50% of the samples were killed, were calculated for cane (cambial region), bud and bud base of each genotype. Red, purple, and black raspberries had a lower T_{50} values than did blackberries. The T_{50} value of *Rubus idaeus* L. cv. Burnetholm canes was -34C. Hardy summer bearing red raspberries, 'Canby' and 'Puyallup' had a T_{50} value of -30C; 'Canby' buds -26C; Puyallup -20C. The T_{50} values of fall fruiting red raspberries, such as 'Zeva Remontante,' 'Indian Summer,' 'St. Regis,' and 'Fallred,' ranged from -23 to -25C. Several purple raspberries (*Rubus neglectus* Peck cvs. Brandywine, Royalty) were quite cane hardy, with T_{50} values lower than -33C. The buds and bud bases of these purple raspberries, however, had T_{50} values at most -25C. Canes of several black raspberries (*R. occidentalis* L. cvs. New Logan, Bristol) had T_{50} values of -28C; buds -27C and -17C, respectively. 'Bristol' offspring had T_{50} values as much as 15C less than the parent. Canes of the hardiest blackberry cultivar, (*R. sp.* cv. Black Satin) had a T_{50} value of -23C; buds were -19C. In many raspberry and some species genotypes examined, the region of the bud at the axis at the cane was less hardy than were tissues within the bud scales. The T_{50} values of canes of most cultivars ranged from about 2 to 15 degrees hardier than buds.

Introduction

Interest in *Rubus* cold hardiness has been increasing in recent years all around the world and particularly in the Pacific Northwest due to cold winters which have caused economic injury to caneberry crops. Despite occasional low killing temperatures, producers want to extend the production range of many types of raspberries, hybrid berries and blackberries to more northerly environments or stabilize production in present areas. Researchers have begun screening to determine which cultivars match those needs.

Several techniques have been used to select for cold hardiness. Sakai et al. (9) established a pre-conditioning treatment to determine the "maximum mid-winter cold hardiness" level in plants. This pre-conditioning regime was applied in this study. Other scientists (4) feel that this regime evaluates the capacity of plants to acclimatize to the control conditions. We used this regime as a standardization procedure, and will refer to the T_{50} values as relative hardiness measurements.

Freezing injury to raspberries (1, 11) and trailing blackberries (1) has

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