12. Mainland, C. M., W. E. Ballinger and L. J. Kushman. 1971. Recovery, firmness and shelf-life of hand and machine-harvested highbush blueberries. *HortScience* 6:309. (Abstr.)
13. ———., ———., and ———. 1971. Effect of mechanical harvesting and sorting upon recovery, firmness and shelf-life of hughbush blueberries. *Proc. Assn. Sou. Agr. Workers 68th Ann. Conv.* p. 178.
14. Norris, K. H. and W. L. Butler. July 1961. Techniques for obtaining absorption spectra on intact biological samples. *I.R.E. Trans. on Bio-Med. Electronics BME* 8(3):153–157.
15. Woodruff, R. E., D. H. Dewey, and H. M. Sell. 1960. Chemical changes of Jersey and Rubel blueberry fruit associated with ripening and deterioration. *Proc. Amer. Soc. Hort. Sci.* 75:387–401.

Effect of Season, Location, Cultivar, and Fruit Size upon Quality of Light-Sorted Blueberries[1]

L. J. Kushmann and W. E. Ballinger[2]
USDA, ARS and North Carolina State University, Raleigh

Abstract. Regardless of season, location, harvest date, or size, 'Wolcott' blueberry fruits sorted with transmitted light according to their anthocyanin (ACY) contents were reasonably well separated for quality as expressed by pH, titratable acid (AC), soluble solids (SS) and the SS/AC ratio. Quality of fruits of the same ACY class differed according to cultivar ('Wolcott', 'Berkeley', and 'Jersey'). AC content of the fruit decreased slightly during the season regardless of ACY class or cultivar. This consistent reduction in AC as the season progressed was accompanied by increases in the SS/AC ratios and development of decay. Location of harvest (farm to farm) influences SS somewhat. A long harvest interval produced a small but consistent effect on all quality parameters.

When harvested by hand, generally unbruised ripe or overripe fruits are placed directly into pint containers in which the fruit is transported to market. There is neither opportunity nor means to visually separate ripe from overripe fruits.

Recent development of mechanical blueberry harvesters has produced a need for new methods of grading and packaging the fruits. Fruits arrive at the grading station in bulk and may be green, ripe, overripe, bruised, or essentially unbruised (12, 13). The obviously green or mashed fruits are removed by hand on a sorting table. To date, however, there is no way to remove overripe and/or bruised but intact blue fruits because they cannot be readily distinguished from other blue fruit. Since overripe (2, 9, 14) and bruised fruits (4, 8) do not keep well and are of inferior quality, some means is needed to detect and remove them from those fruits suitable for marketing.

In previous (2, 11) or preliminary reports (3, 6) we have shown that quality of individual berries of a given cultivar as expressed by pH, titratable acidity (AC), soluble solids (SS) and the SS/AC ratio, is significantly correlated with ACY content as measured with a light transmission difference meter (LTDM, ΔOD 740–800 nm). Cultivars differed considerably in the relationships of the ΔOD readings to the quality indices of the fruit, as might be expected from the fact that ACY development occurs earlier in the ripening process in some clones than in others (5, 7). Our objective was to determine whether season, location, harvest date, and size affected quality of berries that were sorted by light transmittance (LTDM).

Tests made to measure berry firmness, the effect of bruising upon berry firmness, and the separation of fruits according to firmness with a vibration technique are reported elsewhere (4, 8).

Materials and Methods

The LTDM has been described (11). All fruits were placed on their sides on the LTDM to minimize the effect of fruit orientation in the light path (11).

Fruits were classified according to ΔOD values into 6 ACY classes as follows: below ΔOD 0.200, trace or no ACY; ΔOD 0.200 to 0.249, very low; ΔOD 0.250 to 0.299, low; ΔOD 0.300 to 0.349, medium; ΔOD 0.350 to 0.399, high; and ΔOD 0.400 to 0.499, very high. All fruits from a given harvest were sized first by passing them through grids with holes that differed by 1.59 mm in diam (1/16"). Berries of each size class were sorted into ACY classes until at least 1 pint of fruit was collected for each available ACY class. Representative 50 g samples of each available size-ACY class were frozen and later analyzed for pH, AC, SS, and SS/AC (2, 9, 10). The remaining fruits were stored 1 week in pint pulp cups with acetate caps at 21.1°C (70°F) and 80–90% RH. Shelf-life is expressed as percentage of fruits decayed, by number, after the holding period (12).

In 1969 fruits of 'Wolcott' were harvested weekly from one plot of bushes, and only once after at least 3 weeks of fruit ripening (first harvest) from a second plot of bushes on the same farm (Farm B). Single harvests were made from bushes on 3 randomly-selected farms (Farms A, C, D) in the commercial blueberry area; these bushes had been harvested commercially, at unknown intervals, prior to the test harvests. Replication was not feasible due to the length of time required to lightsort the berries one by one.

Data collected in 1969 showed that size of fruit did not influence the ACY-quality relationship for 'Wolcott.' Harvest interval and season influenced this relationship to some degree. Therefore, in 1970 testing was limited to 1 size within a cultivar. Bushes of 'Wolcott', 'Berkeley' and 'Jersey' were harvested weekly at 1 farm. To obtain a second location for each of the 3 cultivars, we used plots of 'Jersey' and 'Berkeley' at a second farm, and plots of 'Wolcott' at a third farm. Fruits of the most prevalent size, 12.7 to 14.3 mm for 'Wolcott' and 'Jersey' fruits, and 14.3 to 15.9 mm for 'Berkeley' fruits were sorted into the different ACY classes. Samples were handled as above for quality evaluation.

Results and Discussion

'Wolcott' fruit, 1969. When 'Wolcott' fruits of each size were sorted according to ACY content into subclasses, differences in pH, AC, and SS contents within an ACY class, due to fruit size, were small (Table 1). Consequently, the SS/AC ratio and decay were not greatly affected by fruit size (Table 2).

Date and location of harvest produced some fairly consistent responses. The pH of the fruit from bushes harvested only once late in the season, after at least 3 weeks of ripening (Farm B, June 19), was

[1] Received for publication December 26, 1974. Paper No. 4423 of the Journal Series of the North Carolina Agricultural Experiment Station, Raleigh.
[2] Research Plant Physiologist, Agricultural Research Service, USDA (now retired) and Professor, Department of Horticultural Science, respectively. The authors are indebted to John Skinner, Jr. and Eleanor P. Maness for assistance in carrying out the work.

Table 1. Consistency of pH, titratable acidity, and soluble solids of blueberries when harvested from the same or different locations during the season and sorted according to size and anthocyanin (ACY) content, 1969 season[z].

ACY class[y]	Harvest date	Farm	pH of fruit for indicated size (avg. diam. mm)[x]						Titratable acidity (%, as citric) for indicated size (avg. diam. mm)[x]						Soluble solids (%) for indicated size (avg. diam. mm)[x]					
			10.3	11.9	13.5	15.1	16.7	Avg.	10.3	11.9	13.5	15.1	16.7	Avg.	10.3	11.9	13.5	15.1	16.7	Avg.
VL	May 28	A	—	3.28	3.40	3.29	—	3.32	—	1.29	1.14	1.33	—	1.25	—	10.7	11.4	11.5	—	10.9
	June 2	B	3.50	3.45	3.49	3.55	—	3.50	1.45	1.27	1.19	1.08	—	1.25	9.5	9.3	9.6	10.4	—	9.7
	June 4	C	—	3.20	3.30	—	—	3.25	—	1.67	1.40	—	—	1.52	—	9.9	10.2	—	—	10.0
	June 9	B	3.40	3.38	3.39	3.30	—	3.37	1.53	1.26	1.23	1.58	—	1.40	10.3	10.3	10.7	10.9	—	10.5
	June 11	D	3.30	—	—	—	—	3.30	1.13	—	—	—	—	1.13	12.7	—	—	—	—	12.7
	June 19	B	3.60	3.50	3.50	3.40	—	3.50	0.86	0.90	1.01	1.05	—	0.95	8.7	8.1	8.6	8.6	—	8.5
	June 19[w]	B	3.75	3.99	3.49	—	—	3.74	0.77	0.58	0.94	—	—	0.76	7.6	8.0	8.6	—	—	8.1
	Average		3.51	3.47	3.43	3.38	—	3.45	1.15	1.16	1.15	1.26	—	1.17	9.8	9.4	9.8	10.3	—	9.8
L	May 28	A	—	3.56	3.60	3.55	—	3.57	—	0.84	0.78	0.89	—	0.84	—	10.6	10.8	11.4	—	10.9
	June 2	B	—	3.75	3.84	3.85	3.85	3.82	—	0.81	0.68	0.64	0.58	0.68	—	10.6	10.8	11.6	11.6	11.1
	June 4	C	—	3.50	3.65	3.74	3.90	3.70	—	0.94	0.63	0.43	0.51	0.63	—	10.8	11.5	12.2	12.8	11.8
	June 9	B	3.75	3.88	3.85	3.95	3.80	3.85	0.83	0.68	0.57	0.53	0.59	0.64	11.7	11.5	11.9	11.5	11.6	11.6
	June 11	D	3.78	3.60	3.90	—	—	3.76	0.67	0.71	0.51	—	—	0.63	14.0	12.5	13.5	—	—	13.3
	June 19	B	—	3.90	3.90	4.00	3.90	3.92	—	0.53	0.43	0.41	0.48	0.46	—	10.4	10.7	10.6	9.5	10.3
	June 19[w]	B	4.30	4.35	4.39	4.20	—	4.31	0.46	0.36	0.31	0.38	—	0.38	8.8	9.6	9.8	9.9	—	9.5
	Average		3.94	3.79	3.87	3.88	3.86	3.86	0.65	0.69	0.56	0.55	0.54	0.60	11.5	10.8	11.3	11.2	11.4	11.2
M	May 28	A	—	—	3.90	3.89	3.92	3.90	—	—	0.48	0.52	0.46	0.49	—	—	11.9	12.2	12.0	12.0
	June 2	B	—	—	4.38	4.20	4.05	4.21	—	—	0.40	0.40	0.36	0.39	—	—	12.2	12.5	12.8	12.5
	June 4	C	—	3.90	4.00	3.89	3.90	3.93	—	0.41	0.48	0.41	0.44	0.43	—	13.5	13.6	14.1	14.0	13.8
	June 9	B	—	4.20	4.30	4.35	4.30	4.29	—	0.41	0.39	0.33	0.33	0.36	—	13.5	13.8	13.9	14.1	13.8
	June 11	D	4.10	4.10	4.28	4.35	4.40	4.25	0.44	0.41	0.36	0.30	0.28	0.36	18.3	15.9	15.5	14.8	15.7	16.0
	June 19	B	—	4.10	4.30	4.30	4.18	4.22	—	0.57	0.30	0.29	0.32	0.37	—	11.3	12.7	12.8	12.7	12.4
	June 19[w]	B	—	4.61	4.55	4.62	4.71	4.62	—	0.25	0.28	0.26	0.24	0.26	—	11.5	11.4	11.7	12.3	11.7
	Average		4.10	4.18	4.24	4.23	4.21	4.21	0.44	0.41	0.38	0.36	0.35	0.37	18.3	13.1	13.0	13.1	13.4	13.4
H	May 28	A	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	June 2	B	—	—	—	—	4.60	4.60	—	—	—	—	0.30	0.30	—	—	—	—	14.1	14.1
	June 4	C	—	—	—	—	4.00	4.00	—	—	—	—	0.41	0.41	—	—	—	—	16.0	16.0
	June 9	B	—	—	—	4.45	—	4.45	—	—	—	0.34	—	0.34	—	—	—	16.3	—	16.3
	June 11	D	—	4.44	4.49	4.40	4.50	4.46	—	0.31	0.30	0.30	0.32	0.31	—	19.5	18.1	16.6	16.5	17.7
	June 19	B	—	4.55	4.70	4.55	4.40	4.55	—	0.34	0.27	0.24	0.26	0.28	—	14.2	15.5	14.5	14.7	14.7
	June 19[w]	B	—	—	—	4.70	4.71	4.70	—	—	—	0.21	0.20	0.20	—	—	—	14.0	13.6	13.8
	Average		—	4.50	4.59	4.52	4.44	4.49	—	0.32	0.28	0.27	0.30	0.29	—	16.8	16.8	15.3	15.0	15.7

[z] Sorted for size by screening; anthocyanin contents were measured with a light transmission difference meter.
[y] VL = Very low, L = low, M = medium, H = high; anthocyanin classes.
[x] 1.6 mm equals 1/16th of an inch.
[w] Fruit from bushes not picked until June 19.

Table 2. Consistency of soluble solids (%) to acid (%, as citric) ratio and decay (%) of blueberries when harvested from the same or different locations during the season and sorted according to size and anthocyanin (ACY) content, 1969 season[z].

ACY class[y]	Harvest date	Farm	Soluble solids to acid ratio for indicated size (avg. diam. mm)[x]						Decay after 7 days at 21.1°C for indicated size class (avg. diam. mm)[x]					
			10.3	11.9	13.5	15.1	16.7	Avg.	10.3	11.9	13.5	15.1	16.7	Avg.
VL	May 28	A	—	8	10	9	—	9	—	9	11	10	—	10
	June 2	B	7	7	8	10	—	8	—	29	32	33	—	31
	June 4	C	—	6	7	—	—	7	—	44	49	—	—	46
	June 9	B	7	8	9	7	—	8	56	43	40	—	—	46
	June 11	D	11	—	—	—	—	11	19	—	—	—	—	19
	June 19	B	10	9	9	8	—	9	21	—	—	—	—	21
	June 19[w]	B	10	14	9	—	—	11	54	70	—	—	—	62
	Average		9	9	9	9	—	9	37	39	33	21	—	35
L	May 28	A	—	13	14	13	—	13	—	4	8	17	—	10
	June 2	B	—	13	16	18	20	17	—	19	33	43	59	38
	June 4	C	—	12	18	28	25	21	—	24	35	44	—	34
	June 9	B	14	17	21	22	20	19	17	42	58	53	—	42
	June 11	D	21	18	27	—	—	22	34	25	38	—	—	32
	June 19	B	—	20	25	26	20	23	—	87	87	94	—	89
	June 19[w]	B	19	27	32	26	—	26	87	95	97	—	—	93
	Average		17	17	22	22	21	20	46	42	51	50	59	48
M	May 28	A	—	—	25	23	26	25	—	—	9	17	25	17
	June 2	B	—	—	31	31	36	33	—	—	17	66	64	49
	June 4	C	—	33	28	35	32	32	—	—	30	31	54	38
	June 9	B	—	33	35	42	43	38	—	44	49	63	78	58
	June 11	D	42	39	43	49	56	46	—	59	76	85	86	76
	June 19	B	—	20	42	44	40	37	—	97	80	97	99	93
	June 19[w]	B	—	46	41	45	51	46	—	87	98	100	100	96
	Average		42	34	35	38	41	37	—	72	51	66	72	64
H	May 28	A	—	—	—	—	—	—	—	—	—	—	—	—
	June 2	B	—	—	—	—	47	47	—	—	—	—	—	—
	June 4	C	—	—	—	—	39	39	—	—	—	—	—	—
	June 9	B	—	—	—	48	—	48	—	—	—	—	—	—
	June 11	D	—	63	60	55	52	58	—	—	89	96	97	94
	June 19	B	—	42	57	60	57	54	—	—	—	—	—	—
	June 19[w]	B	—	—	—	67	68	68	—	—	—	—	100	100
	Average		—	53	59	58	53	55	—	—	89	96	98	96

[z] Sorted for size by screening; anthocyanin contents were measured with a light transmission difference meter.
[y] VL = very low, L = low, M = medium, H = high; anthocyanin classes.
[x] 1.6 mm equals 1/16 of an inch.
[w] Fruit from bushes not picked until June 19.

higher than the pH of fruit from most other harvests (Table 1). Also, within each of the ACY classes, AC tended to be highest early in the season and lowest late in the season regardless of berry size (Table 1). Because of the reduction in AC during the season, the SS/AC ratio usually increased during the season for all sizes within each ACY class except the one with very low ACY (Table 2). This increase in the SS/AC ratio in each ACY class as the season progressed was associated with an increase in the development of decay in fruits held 1 week at 21.1°C (70°F) (Table 2). This was expected since the SS/AC ratio correlates well with development of decay (2, 9, 14).

The SS content of fruits from the harvest of June 11 at Farm D (Table 1) was higher than that of comparable fruits of other harvests, possibly because of a lower fruit-to-leaf ratio in that planting (1). However, the greatest differences in pH, AC and SS were associated with differences in ACY content. The magnitude and consistency of these differences show that, although there was considerable overlapping of the ranges for adjacent ACY classes, there was very little over-lapping of the ranges for ACY classes separated by another ACY class (Table 3). Ninety-two percent of the samples in the high ACY class contained less than 0.4% acid, were higher than pH 4.25, and higher than 13.9% in soluble solids. In this study, as well as in others (2, 3), 'Wolcott' fruits of this composition exhibit fair to poor shelf-life and are usually considered overripe.

When the data were averaged across fruit sizes, the pH, SS, SS/AC and % decay (after 7 days at 21.1°C (70°F)) increased almost linearly with ACY content (Fig. 1). AC decreased logarithmically as ACY content increased, indicating that this type of relationship may best represent the decrease of acid as determined for individual fruits (14). On the average, the changes in the quality indices associated with change in ACY content indicate reasonably good separation of fruits by the LTDM according to ripeness and quality.

Comparison of cultivars, 1970. Separation of 'Wolcott' fruits, from 3 successive weekly harvests at 2 farms about 50 miles apart, into 5 ACY classes produced data (Table 4) which indicated trends similar to those reported above. For each ACY class, the quality indices were more consistent from harvest to harvest and location to location than from one ACY class to another. The small reduction in AC within each ACY class as the season progressed was observed again. In each ACY class SS/AC ratios and decay were higher late in the season than early.

Comparable data for fruits of 'Berkeley' and 'Jersey' also show that separation into different ACY classes produced reasonably consistent

Table 3. Distribution of acidity, pH and soluble solids of 'Wolcott' blueberry fruit samples separated into 4 anthocyanin classes with a light transmission difference meter[z].

Quality factor	Range	Percentage of samples for indicated anthocyanin class			
		Very low	Low	Medium	High
Acid, %, as citric	1.60-1.79	5	—	—	—
	1.40-1.59	18	—	—	—
	1.20-1.39	24	—	—	—
	1.00-1.19	29	—	—	—
	0.80-0.99	14	19	—	—
	0.60-0.79	5	26	—	—
	0.40-0.59	5	44	48	8
	0.20-0.39	—	11	52	92
pH	4.50-4.74	—	—	15	54
	4.25-4.49	—	11	33	38
	4.00-4.24	—	7	30	8
	3.75-3.99	10	56	22	—
	3.50-3.74	24	26	—	—
	3.25-3.49	61	—	—	—
	3.00-3.24	5	—	—	—
Soluble solids, %	18.0-19.9	—	—	4	15
	16.0-17.9	—	—	—	31
	14.0-15.9	—	4	26	46
	12.0-13.9	5	15	51	8
	10.0-11.9	42	62	19	—
	8.0- 9.9	48	19	—	—
	6.0- 7.9	5	—	—	—

[z] 740-800 nm. Data from consolidation of data in Tables 1 to 5.

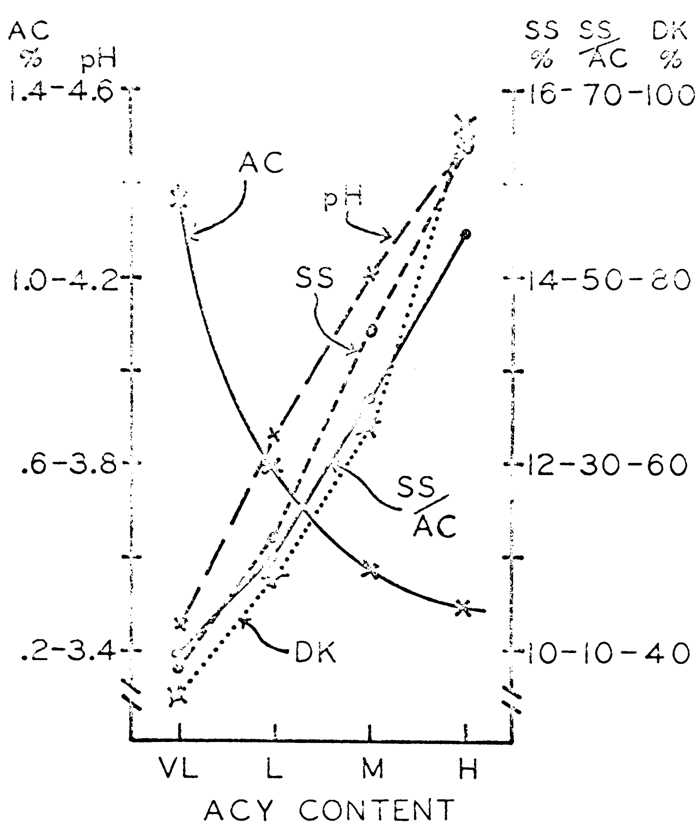

Fig. 1. Avg pH, titratable acidity (AC), soluble solids (SS), SS/AC ratio, and development of decay (DK) of 'Wolcott' fruits as related to anthocyanin content (ACY) measured by light transmittance (ΔOD 740-800 nm) 1969 season. Data from Tables 1 through 5; see text for details. VL, L, M, and H indicate very low, low, medium and high ACY contents, respectively.

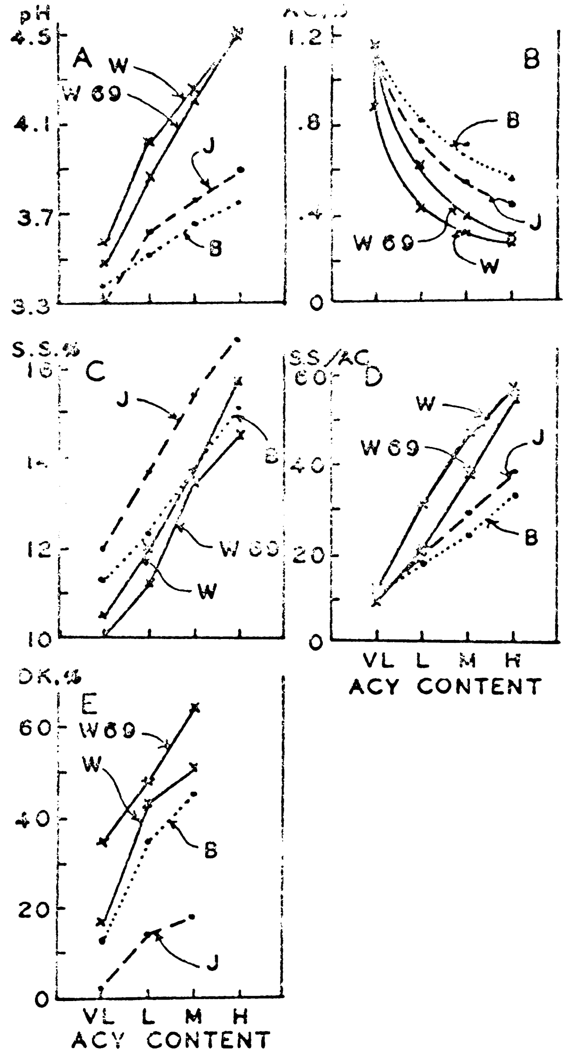

Fig. 2. Avg pH, titratable acidity (AC), soluble solids (SS), SS/AC ratio, and development of decay (DK) of 'Wolcott', 'Berkeley' and 'Jersey' fruits as related to anthocyanin content (ACY) when measured by light transmittance (ΔOD 740-800 nm), 1970 season and 'Wolcott' fruits for the 1969 season. From tables 7, 8, and 9 and Fig. 1; see text for details. (VL, L, M, and H indicate very low, low, medium, and high ACY contents, respectively.)

differences in quality regardless of harvest date and location (Table 4); AC, however, decreased as the season progressed. Also, in each ACY class there was usually less AC and a higher pH and SS for fruits of both cultivars when these fruits were obtained from Farm C, as compared to those from Farm A (Table 4).

On the average the 3 cultivars differed in the relationship between the ACY content and related quality factors (Fig. 2). Differences among cultivars have already been shown by data for individual fruits (11). In most respects data for fruit of 'Wolcott' agreed better between seasons than data for 'Berkeley' and 'Jersey'.

Our data indicate that fruit of a given cultivar can be segregated, according to ACY content, into classes of quality representing stages of ripeness. The fact that fruits of different cultivars differ when classified according to their ACY contents indicates that commercially useful parameters for distinguishing unripe, ripe and overripe fruits may be needed for each cultivar, depending upon the definitions for ripeness (or quality) that are developed.

Other work (4, 8) indicated that firmness, especially as it reflects softening due to bruising, should be another useful parameter that might be incorporated in a commercial grading line as a basis for removing fruits softened too much to be of good quality.

Ripeness and firmness, however, must be related to the potential

Table 4. Quality of 'Wolcott' from Farms A and B and 'Berkeley' from Farms A and C, and 3 harvests when sorted, according to anthocyanin (ACY) contents, with a light transmission difference meter (1970)[z].

Quality factor	ACY class	Harvest dates (Wolcott cv.)							Harvest dates (Berkeley cv.)						
		May 25		June 1		June 8		Mean	June 8		June 15		June 22		Mean
		A	B	A	B	A	B		A	C	A	C	A	C	
pH	Trace	3.62	3.30	3.25	3.25	—	—	3.36	3.15	—	3.28	—	—		3.22
	Very low	3.90	—	3.40	3.61	—	3.35	3.57	3.28	3.31	3.30	3.39	3.55	—	3.37
	Low	4.10	3.95	4.09	4.10	3.90	3.99	4.02	3.45	3.55	3.30	3.59	3.55	3.70	3.54
	Medium	4.25	4.35	4.35	4.20	4.10	4.20	4.24	3.45	3.85	3.42	3.79	3.55	3.81	3.65
	High	4.35	—	—	4.62	—	—	4.49	—	—	3.51	3.91	—	3.80	3.74
Acid, %[y]	Trace	1.55	1.76	1.45	1.38	—	—	1.54	1.67	—	1.35	—	—	—	1.51
	Very low	0.87	0.96	0.85	0.73	—	0.90	0.86	1.29	1.10	1.21	0.80	1.11	—	1.08
	Low	0.55	0.50	0.35	0.32	0.38	0.34	0.41	1.39	0.66	0.85	0.56	0.85	0.50	0.80
	Medium	0.36	0.32	0.24	0.27	0.32	0.29	0.30	1.08	0.38	0.92	0.44	0.85	0.44	0.69
	High	0.30	—	—	0.22	—	—	0.26	—	—	0.77	0.39	—	0.43	0.53
SS, %[x]	Trace	10.2	9.9	9.8	9.5	—	—	9.9	11.2	—	10.3	—	—	—	10.8
	Very low	10.2	11.5	10.2	9.8	—	10.7	10.5	11.1	11.4	11.1	11.4	11.3	—	11.3
	Low	11.4	12.3	11.2	11.4	12.6	12.9	12.0	11.3	13.0	11.5	12.6	12.1	13.3	12.3
	Medium	13.0	13.9	13.1	13.1	14.3	15.0	13.7	12.9	14.2	13.0	13.7	13.3	15.0	13.7
	High	14.2	—	—	14.7	—	—	14.5	—	—	14.3	15.0	—	16.1	15.1
SS/AC	Trace	7	6	7	7	—	—	7	7	—	8	—	—	—	8
	Very low	12	12	12	13	—	12	12	9	11	9	14	10	—	11
	Low	21	25	32	36	33	38	31	8	20	14	23	14	27	18
	Medium	36	43	55	49	45	52	47	12	37	14	31	16	34	24
	High	47	—	—	67	—	—	57	—	—	19	39	—	40	33
Decay, %[w]	Trace	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Very low	7	10	25	26	—	—	17	18	—	6	—	14	—	13
	Low	9	21	36	47	68	75	43	36	30	13	39	56	—	35
	Medium	15	30	61	60	72	67	51	29	52	52	33	78	23	45
	High	—	—	—	—	—	—	—	—	—	—	36	—	—	36

[z] All fruits from 8/16 to 9/16th inch in diam. (12.7 to 14.3 mm).
[y] Titratable acidity expressed as percent citric acid.
[x] Soluble solids from refractometer.
[w] Decay, as percent by number, of fruits held 1 week at 21.1°C (70°F) and a high relative humidity.

Table 5. Quality of 'Jersey' blueberry fruits from 2 farms (A & C) and 3 harvests when sorted, according to anthocyanin contents, with a light transmission difference meter (1970)[z].

Quality factor	ACY class	Harvest dates						Mean
		June 8		June 15		June 22		
		A	C	A	C	A	C	
pH	Trace	3.11	—	3.15	—	—	—	3.13
	Very low	3.25	3.23	3.35	3.30	3.30	—	3.29
	Low	3.45	3.60	3.60	3.60	3.60	3.80	3.61
	Medium	—	3.85	3.65	3.72	3.65	3.82	3.74
	High	—	—	—	3.88	—	—	3.88
Acid, %[y]	Trace	1.96	—	1.83	—	—	—	1.90
	Very low	1.21	1.21	1.16	0.96	1.16	—	1.14
	Low	0.85	0.75	0.72	0.75	0.65	0.53	0.71
	Medium	—	0.56	0.50	0.50	0.58	0.52	0.53
	High	—	—	—	0.43	—	0.40	0.42
SS, %[x]	Trace	11.6	—	10.2	—	—	—	10.9
	Very low	12.0	13.3	10.9	12.6	11.3	—	12.0
	Low	12.2	14.2	12.1	15.0	13.3	15.1	13.7
	Medium	—	15.8	14.2	15.6	15.8	15.8	15.4
	High	—	—	—	16.5	—	—	16.5
SS/AC	Trace	6	—	6	—	—	—	6
	Very low	10	11	9	13	10	—	11
	Low	14	19	17	20	21	29	20
	Medium	—	28	28	31	27	30	29
	High	—	—	—	38	—	—	38
Decay, %[w]	Trace	—	—	—	—	—	—	—
	Very low	4	2	1	—	—	—	2
	Low	7	20	4	8	32	—	14
	Medium	—	28	6	8	35	14	18
	High	—	—	—	—	—	—	—

[z] All fruits from 8/16 to 9/16th inch in diam. (12.7 to 14.3 mm).
[y] Titratable acidity expressed as percent citric acid.
[x] Soluble solids from refractometer.
[w] Decay, as percent by number, of fruits held 1 week at 21.1°C (70°F) and a high relative humidity.

culinary use of the fruits. Preliminary (unpublished) data show that tasters can distinguish fruits that differ in ripeness by 0.5 OD, and that such fruits make pies or tarts that differ in consistency and taste. Furthermore, blends of unripe green and red fruits (classed as VL in ACY) and overripe fruits (classed as H in ACY) might be pureed and used in cooked products. Consequently, more data are needed to establish classifications of ripeness and firmness that indicate fruit quality and potential uses, including uses for fruits not ripe enough, too ripe, or too soft to be useful in the fresh market but useful as processed products.

Literature Cited

1. Ballinger, W. E., and L. J. Kushman. 1969. Relationship of nutrition and fruit quality of 'Wolcott' blueberries grown in sand culture. *J. Amer. Soc. Hort. Sci.* 94:329–335.
2. ———, ———. 1970. Relationship of stage of ripeness to composition and keeping quality of highbush blueberries. *J. Amer. Soc. Hort. Sci.* 95:239–242.
3. ———, ———. 1970. The relation of size and color intensity to quality and shelf-life of blueberries. (Abst.). *Proc. Sou. Agr. Workers* 67th Ann. Conv., Memphis, TN. Feb. 1–4, p. 156.
4. ———, ———, and D. D. Hamann. 1973. Factors affecting firmness of highbush blueberries. *J. Amer. Soc. Hort. Sci.* 98:583–587.
5. ———, E. P. Maness, G. J. Galletta, and L. J. Kushman. 1972. Anthocyanins of ripe fruit of a "pink-fruited" hybrid of highbush blueberries, *Vaccinium corymbosum* L. *J. Amer. Soc. Hort. Sci.* 97:381–384.
6. ———, J. N. Yeatman, and L. J. Kushman. 1968. Progress in maturity measurement of blueberries using light transmittance technique (Abstr.) *HortScience* 3:99.
7. Galletta, G. J., W. E. Ballinger, R. J. Monroe, and L. J. Kushman. 1971. Relationships between fruit acidity and soluble solids levels of highbush blueberry clones and fruit keeping quality. *J. Amer. Soc. Hort. Sci.* 96:758–762.
8. Hamann, D. D., L. J. Kushman, and W. E. Ballinger. 1973. Sorting blueberries for quality by vibration. *J. Amer. Soc. Hort. Sci.* 98:572–576.
9. Kushman, L. J., and W. E. Ballinger. 1963. Influence of season and harvest interval upon quality of 'Wolcott' blueberries grown in eastern North Carolina. *Proc. Amer. Soc. Hort. Sci.* 83:395–405.
10. ———, ———. 1968. Acid and sugar changes during ripening in 'Wolcott' blueberries. *Proc. Amer. Soc. Hort. Sci.* 92:290–295.
11. ———, ———. 1975. Relation of quality indices of individual blueberries to photoelectromeasurement of anthocyanin content. *J. Amer. Soc. Hort. Sci.* 100:561–564.
12. Mainland, C. M., W. E. Ballinger and L. J. Kushman. 1971. Recovery, firmness, and shelf-life of hand and machine harvested highbush blueberries. (Abst.) *HortScience* 6:309.
13. ———, ———, and ———. 1971. Effect of mechanical harvesting and sorting upon recovery, firmness, and shelf-life of highbush blueberries. *Proc. Assn. Sou. Agr. Workers* 68th Ann Conv. p. 178.
14. Woodruff, R. E., D. H. Dewey, and H. M. Sell. 1960. Chemical changes of 'Jersey' and 'Rubel' blueberry fruit associated with ripening and deterioration. *Proc. Amer. Soc. Hort. Sci.* 75:387–401.

Inheritance of Fruit Detachment in Strawberry[1]

G. R. Brown[2] and J. N. Moore[3]

University of Arkansas, Fayetteville

Abstract. Diallel crosses were used to determine the inheritance patterns for capping percentage, capping force, and pedicel breaking force in *Fragaria* × *ananassa* Duch. cultivars. The diallel crosses were evaluated with the Jinks-Haymen formulae and these results were compared with the phenotypic evaluation of the parent cultivars. Capping percentage, capping force, and pedicel breaking force are different genetic traits but they were significantly correlated with each other. The pattern of inheritance for each trait was controlled by both additive and dominant genes. The overall direction of dominance for the respective traits was for higher capping percentage, lower capping force and lower pedicel breaking force. 'Gorella' exhibited extreme overdominance for low capping force. Because of the large environmental influence on these traits, progeny tests such as diallel crosses provide a better evaluation of the genetic potential of a cultivar than its phenotypic performance.

An effective method of mechanically harvesting strawberries is necessary to stabilize the strawberry industry in the United States (4, 9). Various systems of mechanical harvest are currently being proposed and tested (2, 4, 8, 9). Harvest mechanization of other fruits and vegetables has often required the consideration of plant traits that previously were of little importance. Capping and pedicel breaking may be such traits for the strawberry. Typically, in hand harvest the fruit caps or the pedicel breaks. These two areas of separation are comparable to the two abscission areas reported for cherries (6), though the strawberry fruit does not naturally abscise. Capping is defined as the removal of the fruit from the plant with the calyx remaining attached to the plant, and pedicel breaking occurs when the fruit stem breaks, leaving the calyx attached to the fruit.

The commercial strawberry (*Fragaria* × *ananassa* Duch.) is an octaploid with × = 7; 2N = 56 chromosomes (7), but it often behaves genetically as an amphidiploid (11, 12). Strawberry cultivars are asexually propagated. Though they often behave as amphidiploids, they are not homozygous and genetic ratios are frequently complex.

The purpose of this study was to determine the pattern of inheritance for capping and for pedicel breaking so that these characters could be more quickly incorporated into commercial cultivars.

Materials and Methods

Based on literature reports (7) and personal observations, we separated strawberry cultivars into 4 classes for capping ease. Two cultivars in each classification were selected for use as parents for the diallel analysis. The capping classification used and the cultivars selected were: easy; ('Juspa' and 'Gorella'), good; ('Tennessee Beauty' and 'Fresno'), average; ('Blakemore' and 'Albritton') and difficult; ('Surecrop' and MD-US 3082).

All research was conducted at the University of Arkansas Main Experiment Station, Fayetteville. The 8 cultivars were crossed in all possible combinations in the winter of 1969–1970 and the reciprocals were combined. In addition, 'Juspa' and 'Surecrop' were selfed. The fruit was collected when mature and the seeds extracted with a laboratory blender, air dried, and planted in flats containing a mixture of ½ peat and ½ sand. The seedlings upon emergence were

[1] Received for publication December 27, 1974. Published with the approval of the Director of the Arkansas Agricultural Experiment Station.

[2] Present Address: MO State Fruit Experiment Station, Mountain Grove.

[3] Department of Horticulture and Forestry.