Table 2. Characteristics of 'Delicious' apples on commercial harvest dates.

Observation	England[z]	New York State U.S.A.[y]
Growing season	1981	1960–1980
Latitude (°N)	51.3–52.0	41.5–43.0
Orchard blocks	3	numerous
Fruit diameter (mm)	66–74	77–82
Firmness (kg)	8.6–10.0	7.7–8.2
Total soluble solids (%)	13–15	10–11
Core starch (IKI reaction)	slight–moderate	none
Varietal flavor	trace–slight	trace–slight
Watercore	moderate–severe	none–slight
Fruit attachment to spur	loosening	loosening–loose
Calendar dates of harvest	Oct. 17–22	Oct. 1–15
Full bloom to harvest (days)	164–165	130–150

[z]The ranges for tissue analyses are for apples harvested on the commercial harvest date at 51.3°, 1 day after the commercial harvest date at 52.0°, and the average for 2 harvest dates either side of the commercial harvest date at 51.8°.

[y]Typical data (2) and the author's unpublished data.

Table 3. Tissue analyses and fruit attachment to spur at harvest for 'Delicious' apples growing at 54.1° N. latitude.

	Internal ethylene					
Days after bloom	Avg (ppm)	>0.5 ppm (% of apples)	Fruit diam (mm)	Firmness (kg)	Total soluble solids (%)	Watercore (% of apples)
153	0.13	0.0	63	10.8	10	46.6
160	0.10	0.0	60	10.7	11	62.5
170	0.07[z]	13.3	60	10.9	12	93.3

[z]Not including 2 apples (see next column) with >0.5 ppm.

may have been related to the lower total heat accumulation (Table 1). However, it has been shown that 'Delicious' development period is not related to heat unit accumulation during the growing season (1, 3). Another explanation for the delayed AEP was the commencement of below 10° average daily temperatures at 140 days past bloom (Fig. 2).

Commercial harvest in the 3 orchards located at 51°–52° latitude occurred at 164–165 days after full bloom. In comparison with 'Delicious' grown in New York State (Table 2), these apples were smaller, more firm, had higher total soluble solids, more starch in the core area, and more watercore. The development of varietal flavor and looseness on the spur were similar in the 2 regions.

When the last samples were picked in these 3 orchards at more than 170 days after bloom, harvest drop was less than 10% of the crops (data not shown), even though many apples had initiated AEP several weeks earlier (Fig. 1) and consequently had very high internal ethylene concentrations. The delayed abscission by early AEP apples undoubtedly was related to the cold temperatures in the orchard (10).

In the orchard at 54° latitude the apples were very hard (Table 3), there was a moderate amount of starch in the cores, varietal flavor was lacking, and the apples were still tightly attached to the spurs at 170 days after bloom. Unfortunately at this northern location, all the remaining apples had to be picked at 170 days (November 2) to avoid freezing on the tree. The failure to attain harvest maturity in the orchard was probably related to the greatly delayed initiation of AEP.

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A Measurement Technique for 'Delicious' Apple Shape[1]

Eric D. Kuhn,[2] John T. Ambrose,[2] and C. Richard Unrath[3]
North Carolina State University, Raleigh, NC 27650

Additional index words. *Malus domestica*

Abstract. **A simple measure of fruit asymmetry was used to evaluate fruit shape in 'Delicious' apple (*Malus domestica* Borkh.). The maximum/minimum length ratio, the ratio of the maximum distance between an individual calyx lobe and the stem end shoulder of the fruit to the minimum distance between calyx lobe and stem end shoulder, gave consistent results for evaluating normal and abnormal fruit shape.**

Fruit shape, among other characteristics, is considered when determining fruit quality. Because fruit with good shape bring a higher market price, techniques which improve fruit shape are desirable. Hence, an accurate measure for evaluating the effectiveness of growing practices on fruit shape is needed.

The characteristics which constitute good fruit shape vary with species and cultivar. The shape of 'Delicious' apples is characterized as being "conic with 5 more or less distinct ribs and 5 crowns on the shoulders at the calyx end" (1). There are 3 distinct characteristics in this description: conic shape, distinct ribs, and crowns at the calyx end. Each may need to be evaluated by a different parameter.

Researchers have used measures such as "length/diameter ratio" or "length/breadth

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[2]Department of Entomology.
[3]Department of Horticulture.

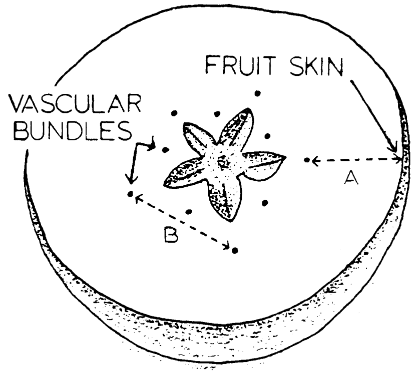

Fig. 1. Diagram of halved apple with seeds removed. A is the shortest distance from the vascular bundle to the fruit's skin and B is the vascular bundle distance.

Table 1. Comparative abilities of several fruit measurement ratios to differentiate between normal and misshapen 'Delicious' apple samples. Comparisons are between the means for each individual misshapen sample and the single uniform sample.

	Ratio		
Sample^z	Maximum/minimum length ratio	Maximum/minimum VB distance ratio	Maximum/minimum VB distance to skin ratio
Normal	1.082	1.574	1.326
Misshapen			
1	1.254*	1.559	1.294
2	1.232*	1.507	1.284

^z Each sample contained 25 apples.
*Significantly different from normal sample at 5% level (F test).

ratio'' for evaluating the overall shape characteristic of apple. For 'Delicious' this measure would be conic shape (2, 3, 4). These measures have been used to evaluate general growth patterns (changes in length and width) over the period of a growing season and to evaluate how effectively certain chemical applications can enhance the conic shape of 'Delicious' apple (2, 3, 4). Length/diameter (L/D) ratios are useful in evaluating the general conic shape of 'Delicious' apple, but these ratios do not evaluate the ''crowns'' characteristic of the apple. Stembridge and Morrell (2) developed a subjective rating scale of 1–4 for evaluating the calyx crown of 'Delicious' apple, but they did not develop a nonsubjective parameter. Reported here is an accurate and simple method for evaluating misshapenness in 'Delicious' apples.

Three samples of 25 'Delicious' apples were selected. Two of the samples were made up of apples that were subjectively determined to be malformed in shape, all showing some degree of lopsidedness. The remaining sample was made up of apples that were graded as uniform in shape.

The following data were taken on each apple: fruit diameter; fruit lengths, or the distance between each individual calyx lobe and the top of the fruit; vascular bundle (VB) distance (Fig 1-B); and distance from VB to skin (Fig 1-A). Fruit diameter was measured using a rule accurate to 0.254 mm (0.01 inch), and the other measurements were made with a dial caliper accurate to 0.0254 mm (0.001 inch).

Using these data, the following variables were created; L/D ratio (maximum fruit length/fruit diameter); maximum/minimum length ratio (maximum fruit length/minimum fruit length) (Fig 2); maximum/minimum VB distance ratio (maximum VB distance/minimum VB distance); maximum/minimum VB distance to skin ratio (maximum VB distance to skin/minimum VB distance to skin). For each of these ratios, a uniform fruit would approach a value of 1.0. Values increasing from 1.0 would show increasing misshapenness.

Maximum/minimum ratios were compared statistically to determine which measure was the best indicator of 'Delicious' apple shape (Table 1). Values from the misshapen samples were compared separately with the single normal sample. Only the maximum/minimum length ratio showed a significant difference between misshapen samples and the normal sample.

To further demonstrate the value of the maximum/minimum ratio, 5 apples were subjectively evaluated for shape, were arranged in order of misshapenness, and were photographed (Fig. 3a). The maximum/minimum length ratios for the 5 apples were then calculated and these values were plotted (Fig. 3b), clearly showing the linear relationship between misshapenness and maximum/minimum length ratio. Fig. 3 also demonstrates that this relationship exists regardless of fruit size.

The L/D ratios for these same 5 apples were also calculated and plotted (Fig. 3c). While L/D ratios are an indicator of general fruit shape, they do not measure misshap-

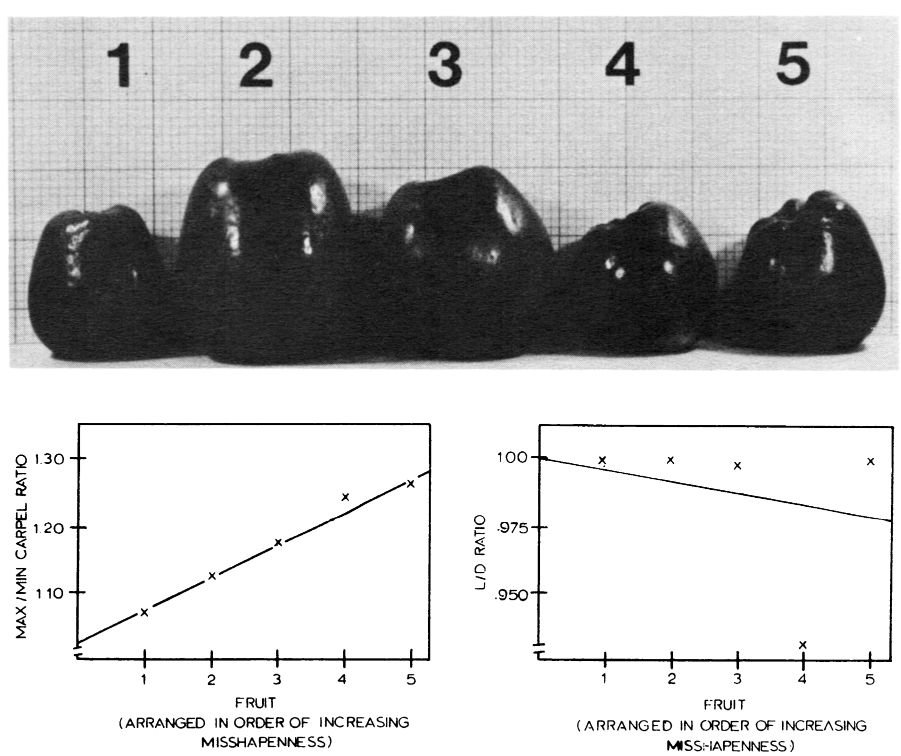

Fig. 3. (a) Photograph of 5 apples subjectively evaluated for shape and arranged in order of misshapenness.
(b) Regression line showing the linear relationship between maximum/minimum carpel ratio and their misshapenness (slope significant at 1% level by AOV procedure, $r^2 = 0.98$).
(c) Regression line showing the relationship between L/D ratio and their misshapenness ($r^2 = 0.13$).

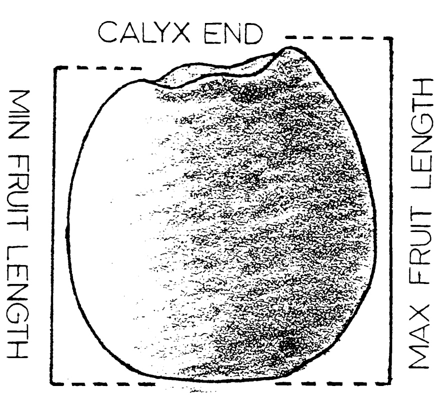

Fig. 2. Diagram of apple showing how maximum and minimum fruit lengths were measured.

enness. Overall, the maximum/minimum VB distance to skin ratio and maximum/minimum VB distance ratio, were not related to misshapenness. However, in some apples seemingly clear relationships existed. Prior to using maximum/minimum ratios, other equations were used: e.g., sum of the fruit lengths/(maximum fruit length × total number of lengths). The values obtained from these equations were statistically no better and were sometimes worse than the maximum/minimum length ratios.

Maximum/minimum length ratio was the only measure that showed consistent usefulness as an indicator of misshapenness. In addition, maximum/minimum length ratios are a simple measure to obtain and statistically easy to evaluate.

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Infestation of Some *Malus* Cultivars by the North Carolina Woolly Apple Aphid Biotype[1]

Eric Young, G. C. Rock, and D. C. Zeiger[2]
North Carolina State University, Raleigh, NC 27650
J. N. Cummins[3]
New York State Agriculture Experiment Station, Cornell University, Geneva, NY 14456

Additional index words. apple rootstock breeding, resistance, *Eriosoma lanigerum*

Abstract. **Seventeen *Malus* cultivars and 6 lines of open-pollinated seedlings were screened for susceptibility to attack by the woolly apple aphid (*Erisoma lanigerum* Hausmann) (WAA) indigenous to western North Carolina. Most cultivars with 'Northern Spy'-derived resistance were susceptible to infestation by this WAA biotype, distinguishing it from WAA reported in other parts of the United States. Some cultivar resistance followed the pattern reported in New York, including high resistnce in Malling Merton (MM) 106, MM 107, and MM 112. Robusta 5 [*M.* X *robusta* (Carr.) Rehd.] was not infested by either the North Carolina or the New York WAA biotypes.**

Resistance to woolly apple aphid (WAA) attack is one of the important traits being sought in apple rootstock breeding programs in the United States and Great Britain (2). 'Northern Spy' [4] has been the standard genetic source for WAA resistance (8, 9) and was used as 1 parent for the Malling-Merton (MM) series of WAA-resistance rootstocks (1). In South Africa (4), Australia (7), and North Carolina (5), WAA biotypes have arisen that are capable of colonizing cultivars with 'Northern Spy'-type resistance. Based on susceptibility trials using WAA indigenous to New York, Cummins et al. (3) concluded that no such biotype has risen in that area. However, they recommend that rootstocks resistant to the New York WAA should be screened for reaction to the North Carolina biotpye. Here we report on the susceptibility of apple cultivars to colonization by WAA indigenous to the apple production region of western North Carolina.

In spring of 1975, 2 sets of *Malus* liners were planted in western North Carolina at the Mountain Horticultural Crops Research Station, Fletcher. One group consisted of open-pollinated seedlings and rooted layers from stoolbeds on the research station. The second consisted of scions of various cultivars grafted to seedling nurse-roots at Geneva, N.Y. The seedlings and rooted layers were planted with the uppermost root 8 cm below soil level, and the nurse-root grafts were planted with the graft union 8 cm below soil level to promote scion rooting. The 2 sets were planted in separate rows 6 m apart. Each row contained 20 randomized single tree replications of each rootstock set about 0.5 m apart. A standard pesticide program was followed, except that the only insecticide used was methiocarb (Mesurol) in 1975 and leptophos (Phosvel) thereafter; these insecticides have no adverse effects on WAA and allowed the native WAA population to increase with minimum predation. Evaluations of WAA susceptibility were made by digging the trees

Table 1. Woolly apple aphid infestation levels on some apple rootstocks propagated in North Carolina.

Malus rootstock	Trees[z] infested (%)	No./infested trees		Infestation[y] rating in New York
		Colonies	Galls	
Open-pollinated seedlings				
M. coronaria	19 def[x]	>100 a	>100 a	---
M. domestica				
Antonovka	37 bcd	15.8 b	34.8 b	Heavy
Ben Davis	72 a	15.2 b	51.7 b	Heavy
Bittenfelder	50 abc	4.3 c	43.7 b	Heavy
Northern Spy	27 cde	9.3 bc	37.3 b	0
Golden Delicious	37 bcd	6.1 bc	37.3 b	Heavy
Vegetatively propagated liners				
M. domestica				
Malling 9	38 bcd	3.8 c	14.0 cd	Very heavy
Malling 25	9 ef	1.0 c	0.0 d	Very light
Malling 26	60 ab	4.4 c	31.7 bc	Very heavy
Malling-Merton 106	5 ef	1.0 c	1.0 d	Light
M. X *robusta*				
Robusta 5	0 f	0.0 c	0.0 d	0

[z]Percent of 20 trees that had at least 1 colony or gall when sampled.
[y]WAA susceptibility ratings reported by Cummins et al. (3) in Geneva, N.Y.
[x]Mean separation within columns by Duncan's multiple range test, 5% level.

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[2]Assistant Professor, Department of Horticultural Science; Professor, Department of Entomology; and Emeritus Associate Professor, Department of Horticultural Science, respectively.

[3]Professor, Department of Pomology and Viticulture.

[4]Cultivars are *Malus domestica* Borkh. unless otherwise stated.