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Fruit Growth Characteristics and Chronological Development of Calyx-end Splitting in Pacific Rose™ Apple

LINUS U. OPARA AND TESHOME TADESSE

Abstract

Calyx-end splitting (CES) is a preharvest physiological disorder, which downgrades the quality of Pacific Rose™ apple fruit, but its causes are not known. Fruit growth characteristics and incidence of calyx-end splitting were monitored on Pacific Rose™ apple. The onset of splitting incidence was at 20 weeks after full bloom (WAFB) and increased progressively with maturity. Fruit growth (diameter, length, and volume) followed an exponential growth pattern. The absolute growth rates (AGR) of diameter and length fluctuated, but showed a declining trend over time, whereas the volume AGR increased until 17 WAFB and declined thereafter. Fruit diameter, length, and volume relative growth rates (RGR) declined exponentially over time. Fruit shape (length/diameter ratio) was characterized by three distinct phases, corresponding to rapid decline (until 18 WAFB), stagnation (18-21 WAFB), and slow rise during the last few weeks before commercial harvest. The onset of CES was preceded by a period of maximum AGR of fruit volume during which fruit shape changed very little. The growth curves of fruit diameter, length and volume respectively, however, did not provide any distinct period with regard to the onset of fruit splitting in the orchard.

Introduction

Apple fruit growth has been studied by a number of researchers and different growth patterns were reported. The classical growth pattern is a slow growth after bloom, then a rapid exponential increase followed by a diminishing rate until ripening. This pattern of growth is sigmoidal (1, 6, 13). Some researchers have also reported a linear (3), curvilinear (expolinear) (7, 8) or a double sigmoid (10) increase in fresh mass, diameter or volume growth. These disparate growth patterns may result from differences in frequency and time of data recording, or using different components of the fruit and analyzing the data on different bases.

There is relatively little difference in the time of blooming of apple cultivars (18), but they vary considerably in their maturity and ripening. Thus, studying the seasonal growth pattern of apple fruit in general and newly introduced cultivars such as Pacific Rose™ apples in particular is very important. Such studies will aid in predicting the maturity stage of the fruit and also assist in determining the time when the fruit is most susceptible to physiological disorders including splitting. Pacific Rose™ apples grown in New Zealand are susceptible to calyx-end splitting (CES) (Figure 1), but the exact causes are not known. Orchard management factors which increase fruit size, such as low crop load and frequent irrigation increased the incidence of stem-end splitting (SES) in 'Gala' apples (11). Exposure of 'Gala' apples to sunlight during growth and development (12) and naphthalene acetic acid (NAA) treatments, which hasten fruit maturity in apples (4) also, increased fruit splitting. Splitting occurs when growth stress causes tissues to be strained beyond their yielding point. During fruit growth and development, growth stresses are likely to be present due to the processes of cell expansion and elongation. For stress to develop in fruit, the tissue must be elastic and growth has to be unevenly distributed (16).

This study was undertaken to characterize the seasonal growth pattern of Pacific Rose™ apple fruit and determine the onset of CES in the orchard.

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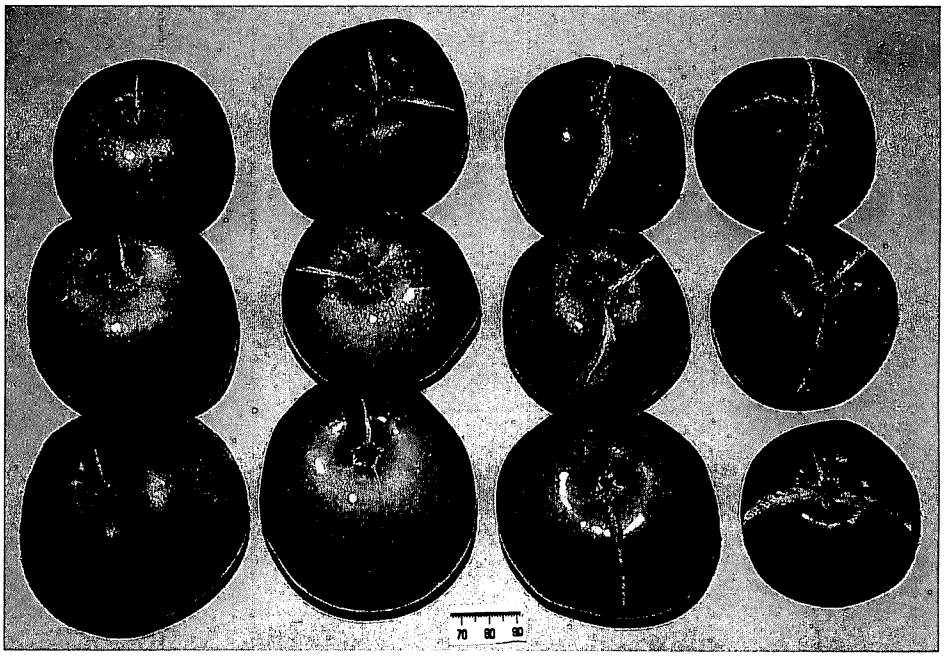


Figure 1. Pacific Rose™ apples with calyx-end splitting.

Materials and Methods

The experiment was conducted in the experimental orchard at Massey University's Fruit Crops Unit (latitude 40.2°S, longitude 175.4°E), Palmerston North, New Zealand. The soil type is predominantly Manawatu sandy loam (5) with a pH of 5.9.

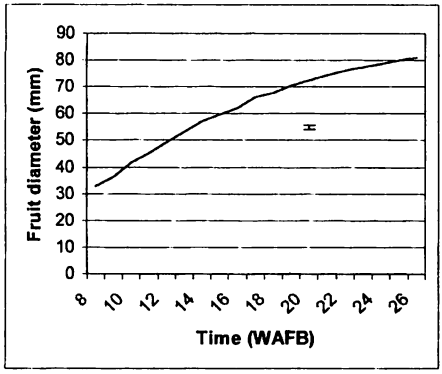
In October 1998, 20 trees of 5-6 year old Pacific Rose™ apple on MM.106 rootstock spaced 3m by 5m, were selected for uniformity of flower bud number. Trees were about 3 meters tall and trained as central leader pyramids.

Shortly after full bloom, a random sample of five fruits per tree on five randomly selected trees was tagged. Fruit size was recorded weekly (starting in November) and continued until harvest maturity (early April). Four measurements (two equatorial diameters of the fruit and the longest and shortest fruit length) were taken for each fruit non-destructively using digital calipers (Model CD-6"C, Mitutoyo Corporation). During the course of the measurement, some fruit abscised; therefore only data from 17 fruits that remained on the tree were used for analysis.

From these measurements, fruit growth was calculated as follows: Absolute Growth Rate (AGR) = $\Delta X/\Delta t$ = [X_2 – X_1/time$_2$ – time$_1$]; Relative Growth Rate (RGR) = $1/X_1 * \Delta X/\Delta t = 1/X_1 * [X_2 - X_1/\text{time}_2 - \text{time}_1]$. Where: X is diameter or length.

Fruit volume was also calculated assuming the fruit to be spherical (1, 15) with the following equation: Volume (V) = $0.16666.\ \pi.\ D^3$ [D = is the mean of the two equatorial diameters and the longest length in mm]. The volume growth rates (mm^3 $week^{-1}$ and mm^3 mm^{-3} $week^{-1}$) were calculated as above. Fruit shape was calculated as the length: diameter ratio (L/D).

The onset of fruit splitting was regularly checked throughout the fruit growth period on 20 trees with an average fruit number of 235 ± 22/tree. The presence of split fruit was recorded by marking split fruit to avoid double counting during subsequent checks. Compression test was conducted from 17-26 WAFB on cortical tissues of



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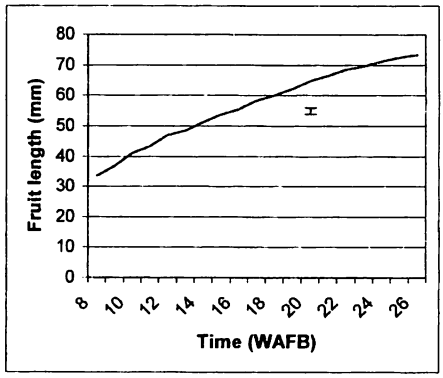

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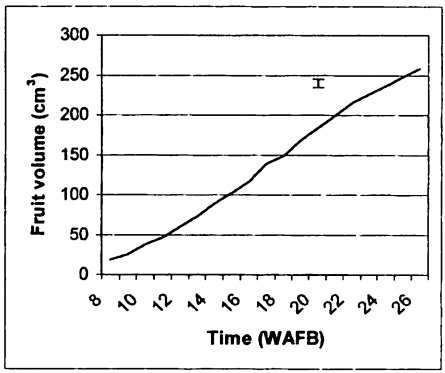

(C)

Figure 2. Cumulative growth of Pacific Rose™ apples (A) diameter, (B) length, and (C) volume. Bars indicate pooled standard error of means.

fruit removed from the blush (red) and non-blush (green) parts of randomly selected apple fruit with a 6-mm diameter cork borer. Seven-mm long tissue samples were then subjected to a force of 0.1N probe using TA-XT2 Texture Analyser (Stable Micro Systems, Godalming, UK). The maximum compression was recorded for statistical analysis.

The data on cumulative fruit growth (diameter, length and volume), growth rates (AGR and RGR) and fruit texture were analyzed as completely randomized design (CRD) by time. Total incidence of splitting was obtained by recording split fruit until commercial harvest. All data were analyzed using SAS program (14).

Results and Discussion

The cumulative growth of fruit in terms of diameter, length and calculated volume are presented in Figures 2A, B, C. The growth curves followed an exponential growth pattern as reported for other apple cultivars (7, 8). The AGR of fruit diameter and length showed a fluctuating but generally decreasing pattern over time (Figures 3A, B). Fruit volume AGR on the other hand, continued to increase until 19 WAFB, but declined thereafter (Figure 3C). Atkinson et al. (1, 2) also reported similar pattern of apple fruit volume AGR. Fruit RGR declined exponentially for all the attributes over the season (Figures 4A, B, C). This is in agreement with other re-

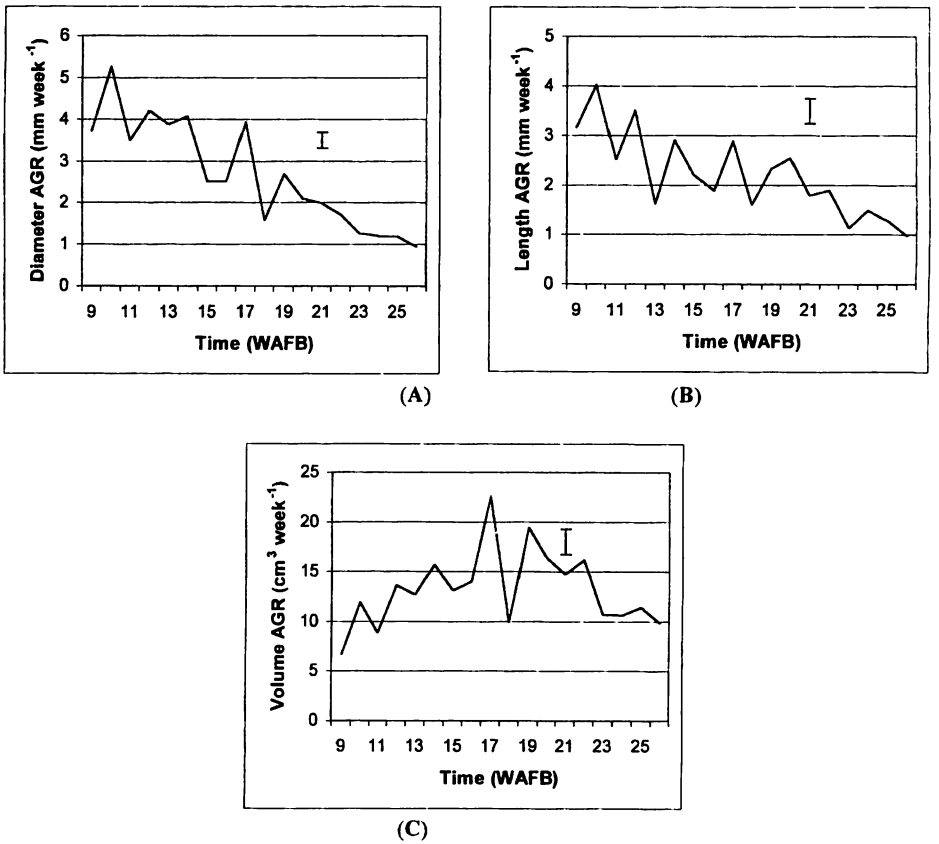

Figure 3. Absolute growth rates of fruit diameter (A), length (B), and volume (C) of Pacific Rose™ apple. Bars indicate pooled standard error of means.

ports (1, 9, 13, 15) regardless of using fruit fresh mass, dry mass, diameter or volume for their calculation of RGR.

Fruit shape exhibited three distinctive growth stages (Figure 5A). There was a stage of rapid decline in L: D ratios from 1.03 to 0.88 (a drop of 14.6%). The second stage was a gradual decline and leveling off (a change of only 1%), which coincided with the onset of splitting, followed by a slight increase in L: D ratio at the last stage (a change of 1.6%).

The incidence of fruit splitting was first observed at 20 WAFB i.e., six weeks before the first commercial harvest of Pacific Rose™ apple in the Manawatu region. After onset, splitting incidence increased steadily with advancing fruit maturity until harvest (Figure 5B). The linear increase in fruit splitting with advancing maturity was associated with a corresponding reduction in tissue firmness (resistance to pressure) which is a measure of loss in microstructural integrity (Figure 5C). However, no appreciable difference was noted in firmness, between the blush (where the incidence is more prevalent) and non-blush sides of the fruit until 25 WAFB ($P \leq 0.05$), although the blush side generally had slightly higher firmness. Studman et al. (17) also observed higher firmness on the red rather than green side of 'McIntosh' apple fruit.

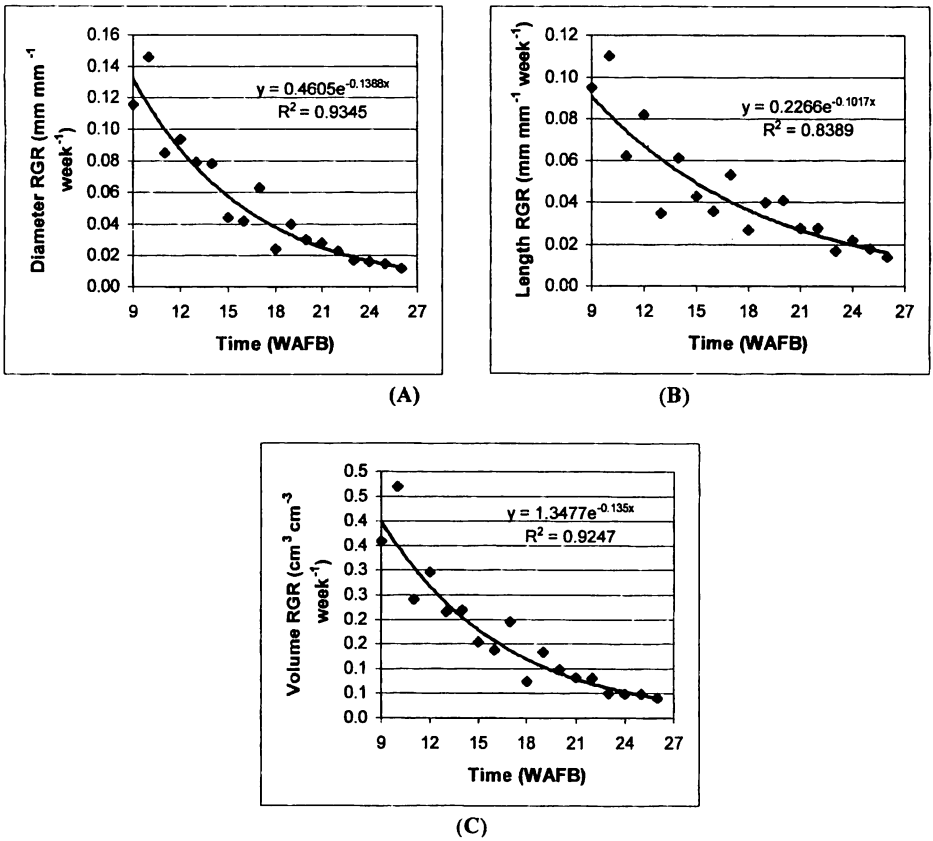

Figure 4. Relative growth rates of fruit diameter (A), length (B), and volume (C) of Pacific Rose™ apple. Bars indicate pooled standard error of means.

Although the evidence in this study does not provide a definite relationship between the onset of splitting and the growth of individual fruit, the data indicates that the onset of splitting during the season coincided with the attainment of final fruit shape i.e. between 18-21 WAFB (Figure 5A). The cumulative growth of diameter, length and volume respectively, however, did not show any particular relationship with the onset of splitting. Further studies are required to ascertain the relationship between individual fruit growth and the susceptibility to calyx-end splitting.

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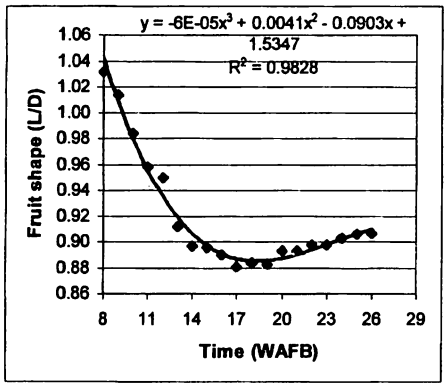

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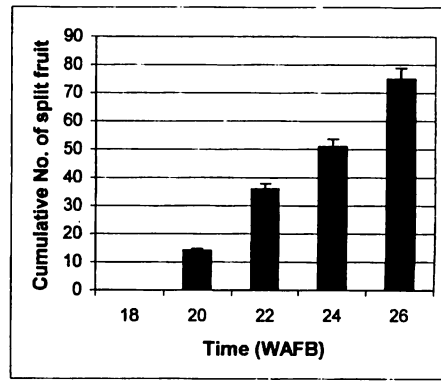

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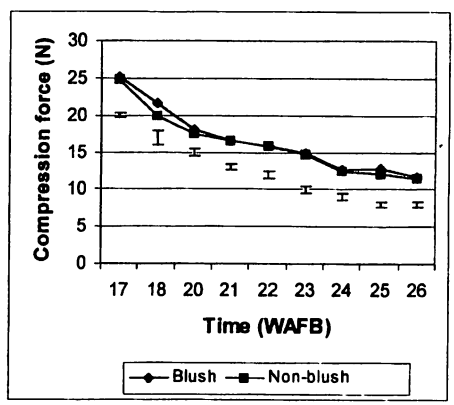

(C)

Figure 5. Fruit shape (A), incidence of splitting (B) and fruit firmness (C) of Pacific Rose™ apple. Incidence of splitting was assessed on 20 trees (235 ± 22 fruits per tree).

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Hartland™ and Somerset™ Sweet Cherries in Denmark

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Abstract

Among 30 newer sweet cherry cultivars planted in a screening trial in Denmark the two Geneva NY, cultivars 'Hartland'™ and 'Somerset'™ have been outstanding in precocity and productivity. The yield has been especially remarkable in years where neighbouring cultivars blooming, on the same day, suffered from spring frost and gave no or only single fruits.

Material and Methods

Thirty cultivars were planted in a screening trial in fall 1994. Three trees of each cultivar were planted on Colt rootstocks at a spacing of 4 x 3 m. The trees were light pruned with a central leader. Management of the orchard was done as normal Danish standard for sweet cherries. In each of three cropping years fruit size, cracking index and fruit firmness were determined on 50 healthy fruits at three harvests with 2-4 days intervals during the ripening season. The cracking index was determined as earlier described (6, 7) over a 6 hours period in distilled water. Full bloom was recorded as the date when 90% of all flowers were open. The productivity of the trees was rated 1-9 (1 = no or single fruits; 9 = very heavy crop) the first three fruiting years, 3rd-5th leaf. (Table 1)

Results

The two cultivars 'Hartland'™ and Somerset'™ were only remarkable in the score for precocity and productivity. Several cultivars suffered from spring frost in 1998 and more in 1999. The average score of yield of the 30 cultivars was only 2,0 and only 'Hartland'™ and 'Somerset'™ had a score higher than 4.

'HARTLAND'™

Origin: Windsor x Open pollination, Geneva, New York. (2), tested as N.Y. 3308. The fruit ripens midseason, it is medium in size and firmness. Unfortunately, it had a high cracking index. The

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