Relationship between Abscisic Acid (ABA) Content and Maturation of the Sweet Cherry

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Summary

The changes in abscisic acid (ABA) content, ethylene evolution, and anthocyanin and sugar contents of the 'Satohnishiki' cherry fruit (Prunus avium L.), and the effect of ABA application on its maturation and coloring were investigated.

1. Among sugars in the fruit, glucose was the highest in content followed by fructose and sorbitol. The total sugar content increased greatly from 38 days after full bloom (DAFB), at which time a concomitant rise in anthocyanin accumulation was also noted.

2. The ethylene evolution per gram fresh weight fell continuously from 17 through 31 DAFB. It increased slightly from 31 DAFB to 38 DAFB, after which it decreased again. In contrast, the ethylene evolution per fruit increased greatly from 31 DAFB.

3. The endogenous ABA levels of the pulp and peel were relatively high on 17 DAFB, but fell to lower levels by 31 DAFB. The ABA content in the pulp increased dramatically from 31 DAFB, while the level in the peel rose slightly from 31 DAFB and more rapidly after 38 DAFB.

4. ABA application to the fruit on 36 DAFB enhanced the total sugar and anthocyanin contents of the fruit.

It is thus suggested that the ABA content may be related to the fruit growth rate, maturation and coloring of sweet cherry.

Introduction

It is well known that the internal ethylene level is related to fruit maturation. In a previous report (Gemma et al., 1991; Kondo et al., 1991), it was suggested that abscisic acid (ABA), as well as ethylene, may be involved in the maturation and coloring of apple, especially in early-harvest cultivars. In grape berries, it has been shown that the onset of ripening is related to ABA levels (Coome and Hale, 1973). Although cherry fruit is a non-climacteric rise type, as is grape berry, its maturation process has not been clearly established.

In the present report, the changes in endogenous ABA, ethylene evolution, and the anthocyanin and sugar contents during fruit development, and the effects of ABA application on the maturation and coloring of the 'Satohnishiki' cherry fruit (Prunus avium L.), were investigated.

Materials and Methods

Experiment 1. The changes in endogenous ABA, ethylene evolution, and anthocyanin and sugar contents during fruit development

Five 6-year-old 'Satohnishiki' cherry trees, grafted onto a 'Colt' rootstock and grown in the open field of Akita Fruit Tree Research Station, were selected for this study. At each sampling, fruits of mean size were collected for analysis from at least three trees at intervals of 6 to 7 days from 17 to 51 days after full bloom (DAFB) in 1990. After the juice of three replicated samples of 10 fruits was extracted and filtered, the sugar content was determined quantitatively by HPLC (Hitachi 655, column GL-C611).
ethylene evolution from three replicates of three fruits, which were sealed in a vial and kept in the dark in a controlled room at 20°C for 15 hr, was estimated from the head-space gas by gas-chromatography (Hitachi 163, column Porapak Q). The ABA content was determined as previously reported (Kondo et al., 1991), including purification by HPLC and identification by GC-MS. For anthocyanin content, three replicates of 1 g lyophilized peel samples were extracted with 1% HCl methanol and filtered, and the absorbance of the solution containing anthocyanin was determined spectrophotometrically at 530 nm.

Experiment 2. The effect of ABA application on the maturation and coloring of fruit

Three 7-year-old cherry trees which were selected in Expt. 1 were used in 1991. A 20% ethanol solution containing 1,000 ppm (S)-(+) -abscisic acid and 0.1% wetting agent (Approach BI) was applied only to the fruits as a dip on 30 DAFB (before coloring) or 36 DAFB (immediately before coloring). From each tree, 75 randomly-selected fruits were treated on 30 or 36 DAFB, and sampled on 46 DAFB. Fruits were rinsed thoroughly with deionized-distilled water, and the sugar, anthocyanin and ABA contents in the pulp and peel were determined as in Expt. 1.

Results

Expt. 1. The changes in endogenous ABA, ethylene evolution, and anthocyanin and sugar contents during fruit development

Fruit growth follows a sigmoid curve when based on fruit fresh weight. Fruit weight increased until harvest time, with the maximum rate of fruit growth occurring from 31 DAFB to 45 DAFB (Fig. 1). Throughout the growth period, the glucose content was the highest, followed by fructose and then sorbitol (Fig. 2). A very small amount of sucrose (less than 0.1 g/100 ml) was detected first at 45 DAFB. The total sugar content increased rapidly after 38 DAFB. Anthocyanin content in the peel fell gradually until 38 DAFB after which it increased dramatically (Fig. 3).

On a fresh weight basis, ethylene evolution from fruits fell continuously from 17 DAFB, increased slightly from 31 DAFB to 38 DAFB, and then showed a continuous decrease until harvest (Fig. 4). However, a large increase in ethylene evolution per fruit was found from 31 DAFB.

The ABA levels of the pulp and peel on 17 DAFB were relatively high, at 18.9 ng·g$^{-1}$ FW and 11.3 ng·g$^{-1}$ FW, respectively, but these fell to lower levels by 31 DAFB. There was a dramatic increase in the ABA content in the pulp after 31 DAFB, from 4.4 ng·g$^{-1}$ FW on 31 DAFB to
72.0 ng·g⁻¹ FW on 38 DAFB (Fig. 5). However, the ABA content in the peel increased gradually from 31 DAFB, with the most notable rate of increase occurring from 38 to 45 DAFB.

Expt. 2. The effect of ABA application on the maturation and coloring of fruit

The ABA content in the peel of fruits applied with ABA was more than that of untreated controls at each application time (Fig. 6). Although the ABA content in the pulp of the 36 DAFB application was 71% higher than that of the untreated control, the ABA contents in the 30 DAFB application and control were almost equivalent.

The effects of ABA application to fruit quality differed with application time. ABA application on the 36 DAFB increased the total sugar content by 17% and marginally increased the anthocyanin content compared to the untreated control, while application on the 30 DAFB failed to increase either sugar or anthocyanin contents (Table 1). However, the rate of water loss from fruits at each ABA application was less than that of the untreated control after 5 days storage at 20°C (Table 1).
The maturation and quality of sweet cherry fruit are affected by environmental and cultural factors, including exposure to light (Patten and Proebsting, 1986), temperature (Watanabe and Taira, 1986), within-tree location (Patten et al., 1986) and leaf area per fruit (Proebsting and Mills, 1981; Roper and Loescher, 1987). Watanabe and Taira (1986) reported that the coloring of cultivars with a red colored peel, such as 'Satohnishiki' and 'Napoleon', was mainly controlled by the lighting conditions. Therefore, the cherry fruits in Expt. 1 were selected from the exterior regions of the tree so as to standardize these effects, and those in Expt. 2 were collected from the whole tree. The coloring of fruits from the tree exterior were generally superior to those from the interior in this experiment (data not shown). It is, therefore, assumed that the higher ABA levels in untreated control fruits in Expt. 1 than in Expt. 2 was based on the within-tree locations of the collected fruit samples (Figs. 5 and 6).

Drake and Fellman (1987) reported that the sugar content and coloring of cherry fruit could be used as indicators of the stage of maturation. In this experiment, the time at which the total sugar content increased and that at which the anthocyanin content increased rapidly coincided at 38 DAFB (Figs. 2 and 3). It is therefore considered that 38 DAFB is around the time when the maturation of the fruit begins.

The endogenous ABA content in the pulp increased dramatically from 31 DAFB, and the ethylene evolution per gram fresh weight increased slightly from 31 DAFB until 38 DAFB (Figs. 4 and 5). These increases preceeded the accumulation of sugar and anthocyanin, suggesting that they may play a role in initiation of the maturation process. Hartmann (1989) reported that ethylene could be the trigger for maturation, since it increased during maturation. However, in this experiment, the ethylene evolution decreased again from 38 DAFB (Fig. 4), so we consider that ABA rather than ethylene may be related to maturation. On a per fruit basis, ethylene evolution increased greatly from 31 DAFB. Thus, whether ethylene gas should be estimated on a per fruit weight basis or per fruit remains to be established.

Davison et al. (1976) showed that ABA levels in the fruit were directly related to the fruit growth rate, being high during the rapid growth phase, i.e., early and late in the process of fruit growth. In contrast, the ABA content in the peel increased slightly from 31 DAFB, but greatly from 38 DAFB when anthocyanin accumulation was noted (Fig. 5).

In this study, ABA application to the fruit on 36 DAFB increased the glucose, fructose and anthocyanin contents (Table 1). Therefore, the results of this study support the notion that the ABA level in the fruit is associated with the rate of fruit growth, as shown in Fig. 1. In addition, ABA levels may well play a role in the maturation and coloring of sweet cherry. It has also been suggested that ABA stimulates the uptake of sorbitol in apple fruit and sucrose in soybean (Beruter, 1983; Gifford and Thorne, 1986). Hence, the increase in sugar content by exogenous ABA treatment indicates that ABA may be related to glucose and fructose accumulation in cherry fruit, in addition to the promotion of maturation. Therefore, the effect of ABA on the maturation of cherry fruit should be investigated further, especially with regards to the sink activity. ABA application to fruit on 30 DAFB failed to increase the sugar and anthocyanin contents. Taira and Watanabe (1986) reported that the sugar and acid contents were

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Glucose (g/100 ml)</th>
<th>Fructose</th>
<th>Sorbitol (g/100 ml)</th>
<th>Sucrose</th>
<th>Total sugar (g/100 ml)</th>
<th>Anthocyanin content (O.D. at 530 nm)</th>
<th>The rate of water loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 DAFB</td>
<td>6.4±0.41</td>
<td>5.3±0.34</td>
<td>1.3±0.14</td>
<td>0.01±0.003</td>
<td>13.0±0.88</td>
<td>0.500±0.073</td>
<td>17.1±0.59</td>
</tr>
<tr>
<td>36 DAFB</td>
<td>7.2±0.49</td>
<td>6.2±0.30</td>
<td>1.8±0.13</td>
<td>0.06±0.013</td>
<td>15.3±0.90</td>
<td>0.583±0.018</td>
<td>17.8±0.79</td>
</tr>
<tr>
<td>Control</td>
<td>6.2±0.13</td>
<td>5.2±0.11</td>
<td>1.6±0.05</td>
<td>0.06±0.004</td>
<td>13.1±0.29</td>
<td>0.557±0.025</td>
<td>18.3±0.99</td>
</tr>
</tbody>
</table>

* 15 fruits for each treatment were stored for 5 days at 20°C. Data shown are the mean±S.E.
slightly decreased by ABA treatment before coloring. Thus, it appears that the effect of ABA application accompanies maturation, while coloring varies with the application time.

ABA application showed a tendency to decrease water loss from fruits stored for 5 days, as shown in Table 1. Similar results have been obtained for apple fruits (Gemma et al., 1991). These results indicate that ABA levels may promote maturation on the tree, but may be inhibitory after harvest.

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Literature Cited


オウトウ果実の成熟とアブシジン酸

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摘 要

オウトウ '佐藤錦' 果実を供試して、内生アブシジン酸 (ABA), エチレン発生量, 果実内糖, およびアントシアニン含量の変化、また果実に ABA を処理し成熟や着色とのかかわりを検討した。

1. 果実内の糖含量は、生育期間を通じてグルコース含量が最も多く、次いでフルクトース、ソルビトールの順となった。全糖含量は満開後 38 日以降急激に増加した。また果皮中のアントシアニン含量も同様な時期に増加した。

2. 果実からのエチレン発生量は、果重 (g) 当たりでは満開後 17 日以降徐々に減少し、満開後 31 日から 38 日にかけてわずかに増加した後再び減少した。果実当たりのエチレン発生量は、満開後 31 日以降大きく増加した。

3. 果肉と果皮の内生 ABA 含量は、満開後 17 日には比較的に高かったが、それ以降満開後 31 日まで減少した。果肉中の ABA 含量は満開後 31 日以降大きく増加し、一方果皮中では満開後 31 日から徐々に増加し、満開後 38 日以降には大きく増加した。

4. 満開後 36 日の果実への ABA 処理は、収穫時の果実内糖含量、果皮アントシアニン含量を増加させた。

以上より、オウトウ果実の生育、成熟および着色に関わる可能性が示唆された。