Preharvest AVG Treatment of ‘Bartlett’ Pear Fruits: Effects on Ripening, Color Change, and Volatiles

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Additional index words. Pyrus communis, aminoethoxyvinylglycine

Abstract. Preharvest treatment with 400 ppm aminoethoxyvinylglycine (AVG) delayed the ripening of ‘Bartlett’ pears kept at 20°C. The effect was not uniform, with the delay in ripening ranging from a few to 112 days. Prolonged storage at 20°C was accompanied by a relatively steady, low level of respiration, gradual degreening, and partial suppression of the eventual climacteric. The combined effect of AVG treatment and prolonged ‘nonripening’ storage at 20°C led to a marked attenuation of the production of 4 readily measurable volatiles including methyl-, ethyl-, and hexylacetate as identified by cochromatography and combined gas chromatography–mass spectrometry. Surprisingly, prolonged storage resulted in a much increased production of 2 other volatile fractions when AVG inhibition was reversed by C2H4 treatment. The emanation of all measured volatiles was closely coincident with the climacteric peak. These observations confirm prior reports of disuniform effects of preharvest AVG treatment and reveal that metabolic transitions during prolonged, nonripening storage may have adverse effects on fruit quality.

AVG, an effective inhibitor of C2H4 synthesis (5), delays the ripening of apples (1, 2, 3, 12) and pears (6, 8, 11). One effect of preharvest AVG applications is to amplify the disuniformity in ripening (8) that normally is observed when pears are not preconditioned with a period of cold storage (10). Irrespective of AVG’s potential as a practical method of controlling ripening, prolongation of the preclimacteric phase provides a means of examining preripening changes as they proceed in “slow-motion” over abnormally long periods of time. In this paper we examine how a prolonged preclimacteric phase affects concomitant changes in color and the subsequent production of some readily measurable volatiles during the delayed climacteric.

Materials and Methods

Fruit and leaves on individual branches of 13-year-old ‘Bartlett’ pear trees were sprayed thoroughly with 400 ppm AVG + 0.1% Tween 20 four weeks and again 2 weeks before harvest. Fruit were harvested at about 4.2 N (18.5 lb) flesh firmness of preharvest AVG applications is to amplify the disuniformity in ripening (8) that normally is observed when pears are not preconditioned with a period of cold storage (10). Irrespective of AVG’s potential as a practical method of controlling ripening, prolongation of the preclimacteric phase provides a means of examining preripening changes as they proceed in “slow-motion” over abnormally long periods of time. In this paper we examine how a prolonged preclimacteric phase affects concomitant changes in color and the subsequent production of some readily measurable volatiles during the delayed climacteric.

Volatiles were measured by stopping the air flow for 30 min or 1 hr (as indicated), withdrawing a 5-ml sample of headspace gas and injecting the sample into a Perkin-Elmer Sigma 3 gas chromatograph equipped with a flame ionization detector and a 3.2 mm × 91.4 cm (⅛ inch × 3 ft) column packed with 4% Carbowax 20M on 100/120 mesh Chromosorb G. Conditions were: carrier gas (N2) at 12 ml/min; injector and detector temperatures 180°C; oven temperature at 50° for 5 min and then increased to 150° at 5°/min. Tentative identification of the volatiles was based on retention times and cochromatography with reagent grade standards. The identity of 3 major fractions was confirmed by mass spectrometry performed at the Facility for Advanced Instrumentation, University of California, Davis. Because assays were nondestructive, all data shown were derived from the same control or AVG-treated fruit. The results of similar experiments carried out over at least 2 successive years are in close agreement.

Results

Color change. The effects of preharvest AVG sprays on prolonging the time to ripening were variable. In tests performed in 1980, 1981, and 1982 the number of days at 20°C required for AVG-treated fruit to begin to ripen and reach the climacteric peak ranged from 25 to 55, 12 to 37, and 20 to 112, respectively. Some degreening took place in all instances where the preclimacteric was prolonged appreciably. This is demonstrated by colorimetric measurements. The first year’s data (Fig. 1) are compromised by the absence of reflectance readings at mid-storage. However, the trend is obvious and confirmed by the next year’s results (Fig. 2). During the climacteric phase of either control or AVG-treated fruit, color change was precipitous and conjoined with the respiratory rise. However, it was clear that a gradual degreening also occurred during the prolonged preclimacteric phase when respiratory rates remained low and relatively steady.

Volatiles. Observed in conjunction with the prolonged preclimacteric was a reduction in ethylene evolution at the climacteric peak to less than 5 µL·kg⁻¹·hr⁻¹ (Fig. 1). This stands in contrast to levels of 80–100 µL·kg⁻¹·hr⁻¹ in control fruit (8). The effects of preharvest AVG treatment and prolonged storage at 20°C on the production of 3 other prominent volatiles is illustrated in Fig. 3. Relative maximum production rates for each of 9 chromatographically distinct volatile fractions measured in 1980 are given in Table 1. Except for peaks #2 and #3, that were seen only with AVG-treated fruit, the suppression of volatiles produced during storage at 20°C brought about by preharvest AVG spraying was dramatic even though the delay in ripening (37 days to the climacteric peak) was relatively modest. Evolution of the volatile fractions (Fig. 3) was closely coincident with the climacteric sequence.
Fig. 1. Prolonged respiratory preclimacteric (– - - –), color change (● ------●), and suppressed ethylene production (● -----●) by AVG-treated pear fruit held at 20°C.

Fig. 2. Respiratory activity (– - - –) and color change (● ------●) for a control and an AVG-treated fruit held at 20°C.

Table 1. Production of volatiles by control and preharvest AVG-treated 'Bartlett' pear fruits.

<table>
<thead>
<tr>
<th>Peak no.</th>
<th>Retention time (min)</th>
<th>Relative peak area</th>
<th>Control</th>
<th>AVG</th>
<th>AVG × 100</th>
<th>Control</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.098 – 0.102</td>
<td>29.2</td>
<td>13.9</td>
<td>48</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>0.31 – 0.32</td>
<td>–</td>
<td>7.9</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>0.51 – 0.59</td>
<td>–</td>
<td>18.9</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4</td>
<td>0.92 – 1.09</td>
<td>100</td>
<td>42.7</td>
<td>43</td>
<td>Methyl acetate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.41 – 1.57</td>
<td>148</td>
<td>48.0</td>
<td>32</td>
<td>Ethyl acetate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.76 – 2.01</td>
<td>104</td>
<td>31.5</td>
<td>30</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>7</td>
<td>2.74 – 3.19</td>
<td>6.4</td>
<td>0.8</td>
<td>12</td>
<td>Propyl acetate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>13.48 – 13.90</td>
<td>16.3</td>
<td>3.3</td>
<td>20</td>
<td>Hexyl acetate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>15.27 – 15.67</td>
<td>1.7</td>
<td>1.3</td>
<td>77</td>
<td>Hexanol</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data from the same fruit shown in Fig. 2 and 3.

Some drift in retention times occurred over the 6-week period of the experiment.

Identity of methyl-, ethyl-, and hexylacetate based on cochromatography with known sample and combined gas chromatography-mass spectroscopy. Propyl acetate and hexanol identified solely by cochromatography.

Data from the subsequent year are shown in Fig. 4 and 5. Ripening disuniformity was clearly evident as some AVG-treated fruit reached their climacteric peak after only 20 days at 20°C whereas others required 112 days (Fig. 4). A decline in maximum "peak" respiratory rates was observed also. C2H4 treatment after 100 days of storage resulted in an enhanced climacteric peak but the effect was modest.

The 6 major volatile fractions produced at or near the climacteric peak by each of the fruit whose climacteric CO2 production is identified (superscript) in Fig. 4, are shown in Fig. 5. Comparisons can be made between controls (open bars), AVG-treated fruit with intermediate delays in ripening (cross-hatched bars), and AVG-treated fruit which did not ripen until treated with C2H4 after 103 days at 20°C (solid bars). All 6 volatile fractions decreased as a consequence of the prolonged preclimacteric phase. After 104 days at 20°C production of methyl-, ethyl-, and hexylacetates was suppressed greatly even though...
C$_2$H$_4$ was used to trigger ripening (Fig. 5BCF). These results corroborate the preceding year’s data (Fig. 3). Among the 3 other volatiles, 2 (Fig. 5AD) were produced in amounts well above control levels following C$_2$H$_4$ treatment and one was not detectable (Fig. 5E).

Discussion

These data, derived from a single spray regime and a limited number of fruit, do not permit definitive assessments of the horticultural uses of preharvest AVG sprays to control the ripening of pears. Nonetheless, the facts that all the comparative data were obtained with nondestructive assays of the same individual fruits and that the same phenomena were observed at least 2 years in succession permit the following conclusions: 1) some ripening-related physiological changes in AVG-treated fruit occurred during prolonged and otherwise “nonripening” storage at 20°C; 2) AVG treatment resulted in a suppression (about 50%) of the production of volatiles even when ripening was only slightly delayed; 3) the production of volatiles was suppressed further during prolonged storage at 20°C to the extent that some normally major components were no longer detectable; and 4) the effect on volatile production appeared not to be uniform, since some new volatiles appeared and some were produced in abnormally high amounts when AVG inhibition was reversed with ethylene.

It is not surprising that some physiological change would occur during the prolonged storage at 20°C. Even though the metabolic rate (CO$_2$ evolution) is only a fraction of that during the climacteric, active metabolism is continuous. To what extent the gradual degreening is emblematic of other physiological changes is unknown although similar color changes accompanying normal ripening were conjoined closely with a decrease in firmness (6).

An obvious consequence of prolonged, nonripening storage at 20°C is the decline in magnitude of the eventual climacteric-related events. This is manifested by the progressively lower climacteric peak in CO$_2$ production (Fig. 4) and, more dramatically, in the suppression of volatiles. A surprising aspect, revealed by the exposure of AVG-treated fruit to C$_2$H$_4$ after 103 days at 20°C, was the observation that some volatiles were now evolved in much greater amounts than by ripening control fruit.

Overall, the findings point to the experimental utility of AVG in facilitating the search for physiological events during a much prolonged preclimacteric phase. As seen above (Fig. 3) and argued elsewhere (8), amplification of the ripening disuniformity suggests that events other than (and preceding) ethylene synthesis control the disposition of pear fruit to ripen. It has been suggested (Bramlage, personal communication) that such disuniformity may reflect differences in physiological development already present when AVG was first applied 6 weeks before harvest. That may well be and it suggests the desirability of more extensive examination of application times, frequency, AVG concentrations, etc.

In terms of volatile production, the prolonged preclimacteric has revealed that, contrary to the implications of some early experiments (7), the emanation pattern of all the volatile fractions measured was closely coincident with the respiratory climacteric, whether or not ripening had been delayed by AVG. This observation does not preclude the possibility that different patterns of evolution may exist for some of the over 30 flavor components that have been extracted from pear tissues (4), some of which may be discernible in headspace samples by more refined techniques (9) than used by us.
Effect of Nitrogen Rate and Water Stress on Growth and Water Relations of Young Sweet Corn Plants

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Abstract. Seedlings of sweet corn (Zea mays L. cv. Iochief) were grown in sand with 3 rates of N at a moderate and severe water-stress rate produced by adding polyethylene glycol (PEG 6000) to the nutrient solution. As water stress increased, dry-matter production decreased. Increasing N rate compensated for the loss in dry-matter production that resulted from the water stress. Leaf chlorophyll levels and stomatal density on the abaxial leaf surface increased with an increase in N, and a faster recovery of the relative water content of leaf tissue following water-stress treatment occurred. All 3 responses could have contributed to the N response in dry-matter production observed at the 2 water-stress levels. A low N rate may aid young sweet corn seedlings under severe water stress to resist drought, as indicated by a stabilization in dry-matter production in plants receiving only 8 mm N in the nutrient solution when moving from moderate to severe water stress. These plants had a higher relative water content and leaf water potential under severe water stress than plants receiving higher rates of N, which may have contributed to the ability of plants receiving a low-N rate to cope with the severe water stress.

The effect of N fertilizer on the water-use efficiency of plants has been studied by various workers (4, 6, 7, 8, 9, 10, 12, 14, 15, 16). Field and laboratory experiments have shown that increased N fertilization could increase the water-use efficiency of various plant species (6, 7, 8, 9, 16). Other workers (14, 15), however, have reported that N-deficient cotton plants could be better-suited to water stress than plants having high-N content. Radin and Parker reported more dry-matter production per unit moisture in plants of low-N content than in plants of high-N content.

The effects of osmotic stress on growth and some physiological processes of young sweet corn plants treated with varying rates of N were investigated in the present work.

Materials and Methods

Plant material. ‘Iochief’ sweet corn seeds were germinated in vermiculite in shallow plastic trays with drainage holes and irrigated with tap water. When the seedlings were at the 3-leaf stage, uniform plants were selected and transplanted in plastic pots containing vermiculite (one seedling per pot) and irrigated...