Effect of a Pinolene-base Antitranspirant on Fruit Growth, Net Photosynthesis, Transpiration, and Shoot Growth of ‘Golden Delicious’ Apple Trees

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Abstract. Sprays of 0.5% poly-1-p-methen-8-9-diyl (Vapor Gard), an antitranspirant, decreased fruit size but had no influence on russet or fruit quality of field-grown ‘Golden Delicious’ apple (Malus domestica Borkh.). Laboratory experiments in growth chambers with potted ‘Golden Delicious’ apple trees indicated that: 1) Vapor Gard at concentrations of 0.25, 0.5, 1.0, and 2.0% tended to decrease net photosynthesis (Pn) and transpiration (Tr) for 1 to 7 days under optimum soil moisture conditions; 2) under conditions of low soil moisture, 2.0% Vapor Gard sprays reduced Pn and Tr significantly, but did not reduce symptoms of injury from moisture stress; and 3) Vapor Gard did not affect shoot growth over a 21-day period.

Film forming antitranspirants are petroleum compounds which in theory form a continuous layer over leaf surfaces that is impermeable to water vapor, but permeable to CO₂ and O₂ (10). These antitranspirants reduced transpiration and increased internal water potential, but also reduced Pn (9, 10).

Peaches (3, 8), cherries (7) and mangos (4) have benefited from antitranspirant applications. Peach fruit size increased 18% when 0.5% Vapor Gard was applied 4 to 5 weeks before harvest (3) and red color of mango fruit increased following application of 5.0% Vapor Gard (4). Other wax-base antitranspirants applied to cherries 10 days prior to harvest increased fruit size 15%, and reduced postharvest fruit shrivel 50% (7).

A 1% oil-wax emulsion applied to ‘Grimes Golden’ apples 1 month prior to harvest resulted in a size increase (11). Wax-emulsions applied to ‘Golden Delicious’ prior to harvest had no influence on fruit size (11). Recent research showed a wax-base compound applied to ‘McIntosh’ apples stimulated red color development (6).

Pinolene-base compounds have not been reported to reduce photosynthesis, but have had a beneficial effect on tree water potential, increased fruit size and quality (2, 3, 4). Research with antitranspirant effects on fruit size, Pn, and Tr is important in selection of a product with the most benefit and the least amount of plant damage. Vapor Gard, a pinolene-base antitranspirant, was selected for these studies because little information was available on its effects on plant Pn, Tr, and apple fruit growth. The objectives of this study were to evaluate the effect of Vapor Gard sprays on: 1) fruit size and quality (russet, color, and firmness) of ‘Golden Delicious’; 2) Pn and Tr of apple leaves under high and low soil moisture conditions; and 3) shoot growth.

Materials and Methods

Field. Twenty-year-old ‘Golden Delicious’ apple trees on seedling rootstocks were separated into 2 parts, a north and south half for treatments as half tree units. Treatments were randomly assigned per half tree to 18 trees. Vapor Gard3 treatments replicated 6 times of 0.5% (by vol) were applied to half trees at the following times during the 1975 season: control (no spray), May 6 (tight cluster), May 23 (petal fall), and at about 40 day intervals, thereafter: July 1, August 8, and Sept. 15. Each set of half tree units was sprayed once with a high-pressure hand-gun sprayer to upper and lower leaf surfaces to the drip point (about 36 liters/half tree). At harvest, the fruit was graded in a weight sizer into 4 size classes and 30 fruit from each treatment were rated for color, russet, and firmness. Color and russet were rated visually and firmness was determined using a Magness-Taylor pressure tester (11.0 mm tip).

Laboratory. These studies were designed to study the effects of Vapor Gard on Pn, Tr, and shoot growth of potted ‘Golden Delicious’ apple trees. ‘Golden Delicious’/Malling 7 was trained to a single shoot and grown in 25 cm plastic pots in a mixture of 3 loam:1 peat:1 perlite for all laboratory experiments. Trees were initially fertilized with 25 g of slow-release fertilizer (14N—6.0P—11.6K) placed on the soil surface, with an additional 500 ml of 200 ppm fertilizer (20N—8.6P—16.6K) added every 2 weeks. Trees were watered daily to leaching, and insects were controlled as needed with materials known to have little influence on Pn. Trees were grown outdoors during the experimental period and transferred to a growth chamber before any Pn and Tr measurements were taken. The growth chamber maintained an 18 hr light period at 21°C (21.6 klx at median tree height), a 6 hr dark period at 15°C and a 60 ± 5% relative humidity.

CO₂ assimilation was measured with an infrared gas analyzer using methods similar to Sharma (13). Transpiration was measured by determination of the dew point of air before and after entering the leaf chamber with a dew point hygrometer (EGG Model 880).

To study the effects of Vapor Gard on young expanding and fully expanded apple leaves sprays of 0.0% (control), 0.5%, 1.0% or 2.0% were applied to the drip point with a hand atomizer to 4 newly opened leaves at the tree apex and 4 fully expanded leaves (determined by modified plastochron index) (13) on each of 6 trees. The 4 Vapor Gard treatments were assigned randomly to the young leaves and also to the fully expanded leaves. The trees were maintained at optimum soil moisture outdoors during the experiment and were transferred to the growth chamber the night before Pn and Tr measurements. Pn and Tr measurements were taken 1, 7, 14 and 21 days after Vapor Gard treatment.

To investigate the effect of Vapor Gard on water-deficient apple trees sprays of 0.0% (control), 0.5% and 2.0% were applied to 6 randomly selected trees. The entire tree was sprayed to the drip point with a pressurized-hand sprayer. These trees, previously maintained at good soil moisture, were transferred to the growth chamber for the duration of the experiment, and no further water was applied. One fully expanded...
leaf (see above) from each tree was measured for Pn and Tr one day prior and 1, 5, and 7 days after Vapor Gard treatment. Observations on leaf necrosis and leaf abscission (indications of water deficiency) were made for 14 days after treatment. To investigate the effects of the antitranspirant on shoot growth, measurements were taken from trees sprayed with 0.0% (control), 0.5% or 1.0% Vapor Gard. Sprays were applied to the entire tree as in the water deficit study. Trees were grown outdoors and good soil moisture was maintained. Shoot growth measurements were taken at 7 day intervals for 21 days.

Results and Discussion

Field. Vapor Gard applied at 0.5% to 'Golden Delicious' apple trees in the field decreased the percentage size 1 (7.9 cm diam and larger) fruit when applied on May 23, July 1 and Sept. 15 with a trend in the same direction for the application on May 6 and August 8 (Table 1). Fruit firmness was significantly different only on fruit from the Sept. 15 treatment when compared to the control. Antitranspirants applied to stone fruit 2 weeks before harvest increased fruit size by up to 18% (2, 6), an increase attributed to an increased plant water potential. Internal water potential was not measured on the apple trees in this study, but rainfall for the growing season was 58 cm (normal 63 cm). This rainfall, although below normal, was evenly distributed and no prolonged dry periods occurred. The typical sigmoid fruit growth curve (14) was observed on the treated apple trees during the 1975 season. Also, Wooster silty loam soils have a high water-holding capacity and antitranspirant sprays may not be as beneficial to apple trees grown in these soils. Apple trees grown on soils with less waterholding capacity may be affected.

Net photosynthesis was not measured in the field, though several factors may have affected Pn and led to differences in the proportions of fruit size observed. All fruit harvested from treated trees tended to be reduced in size. This could indicate that Vapor Gard affected fruit growth. Pinolene compounds have been shown to persist on orange leaves for up to 6 months (1). Any persistence of the spray on the apple leaves could affect the rate of Pn and fruit size could be reduced as a result. Antitranspirants do slow photosynthesis and can affect fruit size (7). The Sept. 15 spray was applied after most Pn, which would affect the 1975 crop, had occurred. Any reduction of Pn at this time would have little effect on fruit size. The reduction of fruit size from the trees treated on Sept. 15 might be explained by the fact that 5 of 6 treatment replications (the result of randomization) occurred on the north half of the tree. Cain (5) reported that the north wall of a hedgerow planting received much less light than the south wall. Less light could result in lower Pn and smaller fruit. The Vapor Gard sprays did not affect fruit russet or color ratings (Table 1).

Laboratory. Preliminary growth chamber studies with Vapor Gard at 0.25%, 0.5% and 1.0% indicated that Pn was reduced significantly on treated leaves 7 days after application. Measurements of Pn on newly-opened and fully-expanded leaves showed that initially Vapor Gard sprays (except 0.5%) significantly reduced Pn on treated leaves (Fig. 1). However, by day 7 only the 2.0% Vapor Gard-sprayed leaves had significantly lower Pn than the controls. A similar pattern was observed for Tr 1 day after treatment. This could indicate that the age of the leaf is important in the response obtained. For the remainder of the experimental period, Pn and Tr ratios were similar on all leaves regardless of treatment.

Averaged overall treatments and controls, the newly-opened leaves initially had lower rates of Pn than the fully expanded leaves (Fig. 2). The young leaves expanded rapidly after Vapor Gard treatment, and by 7 days after treatments Pn was similar to fully expanded leaves. As the young leaves expanded, the Vapor Gard film could become stretched and cracked or application of the spray may have been in patches which would allow free exchange of gases and increased Pn. Pn of the fully expanded leaves remained stable and as the leaf senesced, lower values would occur as shown by Sharma (13). Therefore, timing of sprays in relation to vegetative growth was important for the response obtained.

Vapor Gard applied at 2.0% to potted 'Golden Delicious' trees which were not watered after treatment resulted in significant reductions in Pn (Fig. 3) and Tr (Fig. 4) compared to controls and 0.5% Vapor Gard-treated trees. As the soil water is depleted, stomatal and mesophyll leaf resistance is increased

Table 1. The effect of time of 0.5% Vapor Gard application on size, firmness, color, and russet of 'Golden Delicious' apple fruits, 1975.

<table>
<thead>
<tr>
<th>Date of treatment</th>
<th>Fruit distribution (%)</th>
<th>Fruit firmness (kg/cm²)</th>
<th>Fruit color rating</th>
<th>Fruit russet rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size 1²</td>
<td>Size 2</td>
<td>Size 3</td>
<td>Size 4</td>
</tr>
<tr>
<td>Control</td>
<td>31.1a</td>
<td>16.0a</td>
<td>49.6c</td>
<td>3.1a</td>
</tr>
<tr>
<td>May 6</td>
<td>18.0ab</td>
<td>12.2a</td>
<td>66.8b</td>
<td>2.8a</td>
</tr>
<tr>
<td>May 23</td>
<td>11.0b</td>
<td>12.5a</td>
<td>72.6a</td>
<td>3.8c</td>
</tr>
<tr>
<td>July 1</td>
<td>12.0b</td>
<td>17.7a</td>
<td>66.7b</td>
<td>3.4a</td>
</tr>
<tr>
<td>Aug. 8</td>
<td>18.6ab</td>
<td>10.8a</td>
<td>67.2b</td>
<td>3.1a</td>
</tr>
<tr>
<td>Sept. 15</td>
<td>7.1b</td>
<td>10.7a</td>
<td>78.0a</td>
<td>4.0a</td>
</tr>
</tbody>
</table>

²Fruit diam: Size 1 > 7.9 cm (3-1/8 inch); Size 2, 7.9-7.3 cm (3-1/8 to 2-7/8 inch); Size 3, 7.3 to 5.7 cm (2-7/8 to 2-1/4 inch); Size 4, <5.7 cm (2-1/4 inch).
³Based on a scale of 1 (green) to 5 (yellow).
⁴Based on a scale of 1 (no russet) to 5 (total russet).
⁵Mean separation in columns by LSD, 5% level.
(15). These factors can act to reduce the rate of Pn and Tr. Vapor Gard at 2.0% added another resistance to free movement of CO₂ and water vapor. The reduced Tr could be beneficial to the plant during a stress period if the similarly reduced Pn were not harmful. The Pn and Tr measurements were terminated when the leaves used for the study abscised.

Although drastic reductions of Pn which would appear on highly stressed trees did not occur during the measurement period, the trees had begun to wilt and some leaves had abscised after 7 days with no water.

The water-deficient trees were observed for an additional 7 days after Pn and Tr measurements were concluded. The treated trees and controls had similar amounts of leaf necrosis and leaf abscission. Although the 2.0% Vapor Gard had reduced Tr, it did not delay the onset of initial wilting nor the no. of leaves which abscised.

Vapor Gard sprays of 0.5% and 2.0% did not increase shoot length over a 21-day period (data not shown). An earlier report suggested that if plant water potential was increased due to decreased transpiration, shoot growth may be increased (9). This was not confirmed in this experiment. During the experiment when the trees had a temporary stress due to extremely hot weather, the treated trees had the same amount of wilting and leaf discoloration as controls.

These studies showed that Vapor Gard applied to field-grown apple trees under normal soil moisture conditions decreased fruit size. Laboratory studies on potted apple trees showed that Vapor Gard initially decreased Pn and Tr. Applied to trees which were not watered after treatment, 2.0% sprays of Vapor Gard significantly reduced both Pn and Tr, but did not reduce moisture stress injury of the trees. The stage of leaf development at application and concn of Vapor Gard appear to be the most important factors which affect any response to the sprays.

**Literature Cited**