Effect of Ethylene Source on Abscission of Pepper Plant Organs

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Abstract. Ethylene-induced abscission of pepper (Capsicum frutescens L. cv. Hungarian Hot Yellow Wax) flower buds, leaves, and fruit depended on ethylene source (i.e., ethylene gas from a compressed gas source vs. ethylene released from Silaid) and concentration. In response to ethylene from either source, flower buds and small fruit (<10 mm long) abscised most readily and fully expanded leaves least readily. Concentrations of Silaid that induced fruit abscission comparable to a given concentration of ethylene gas induced significantly greater leaf abscission than ethylene gas. Application of Silaid at dusk resulted in a small, but significant, increase in abscission relative to early morning application. Progressive increases in temperature between 18° and 32°C enhanced fruit and leaf abscission in response to ethylene gas. Abscission mediated by ethylene gas was not affected by light intensities between 120 and 300 μmol·m⁻²·s⁻¹ PAR. Chemical name used: (2-chloroethyl)methylbis(phenylmethoxy)silane (Silaid, CGA-15281).

The influence of ethylene on the abscission of various plant parts has been well documented (1, 27). With the advent of ethylene-releasing compounds, significant interest has developed in the chemical alteration of abscission responses in certain crops (4).

Sprays of ethylene-releasing compounds usually are not directed at the target organ alone, but rather contact most aboveground plant parts. Thus, selective induction of abscission of a particular plant organ requires that the sensitivity of the target organ to the ethylene-releasing compound be sufficiently greater than that of nontarget organs. Leaf abscission, for instance, is often an unwanted response that accompanies foliar sprays of ethylene-releasing compounds to induce thinning, loosening or dehiscence of a variety of fruits (7, 9–11, 15, 21, 22, 30). The effect of released ethylene on nontarget tissues (e.g., induction of leaf abscission) may result in a substantial yield reduction in some perennial species the following year (13, 14, 31).

Environmental factors such as temperature, humidity, and light intensity are known to significantly alter the release kinetics of ethylene from ethylene-releasing compounds (5). Changes in the duration and peak concentration of ethylene exposure also affect plant response (19, 20, 25). High temperatures enhance abscission in several fruits (13, 17, 24, 26, 28) treated with ethylene-releasing compounds. It is unclear, however, whether the effects described are primarily due to temperature-dependent changes in the plant’s response to ethylene, changes in the breakdown rate of the applied chemical, or to their interaction. Lastly, a light-induced change in stomatal aperture is able to modify the movement of ethylene derived from ethylene-releasing compounds (6). This raises the possibility that nighttime stomatal closure alters the effectiveness of ethylene-releasing compounds.

The effect of environmental factors on the sensitivity of the abscission response of various plant parts can be determined by use of ethylene gas. Use of a gaseous ethylene source avoids problems caused by the effect of environmental variables on the ethylene-releasing compound per se and resulting secondary effects upon the plant. However, the use of ethylene gas in model systems to extrapolate to responses mediated by ethylene-releasing compounds relies on several assumptions. One holds that the relative sensitivities of plant parts to the ethylene-releasing compound closely parallel their sensitivity to ethylene gas. To test the validity of this assumption and to further study ethylene-induced responses, pepper plants were used in a model system in which the relative sensitivity of plant parts at various developmental stages was examined using ethylene gas and ethylene from an ethylene-releasing compound, Silaid. We also examined the effect of temperature and light intensity on abscission mediated by ethylene gas and the effectiveness of application of the ethylene-releasing compound just after sunrise or before sunset.

Pepper plants (Capsicum frutescens L. cv. Hungarian Hot Yellow Wax) were seeded weekly and grown in a greenhouse. Seedlings were transplanted 2 weeks after sowing into plastic cell packs (50 × 60 × 55 mm deep) and retransplanted on the 5th week into 150-mm pots containing Cornell mix (8). The plants were watered daily and fertilized weekly with a 200 ppm 10.0N-8.9P-4.3K fertilizer solution. A single application of 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime (Temik; Union Carbide, Jacksonville, Fla.) (10.6g·m⁻²·soil surface) was made following transplanting into the pots. Additional insect control involved the application of foliar sprays of dinitro-6-octyl-phenyl-crotonate (karathane; Rohm and Haas, Philadelphia) (2.6 ml·liter⁻¹) and 5,6-dimethyl-2-dimethylamino-4-pyr-imidinyl dimethylycarbamate (Pirimor; ICI Americas, Wilmington, Del.) (1.3 ml·liter⁻¹) as needed. Experiments began 10 weeks after sowing. At this time most plants had produced at least one harvestable fruit (i.e., >25 mm diameter and >90 mm long). Plants were selected for uniformity and grouped into experimental units of three plants each. The plants were then exposed to either a continuous flow of ethylene in air or ethylene evolved as a result of a foliar application of Silaid.

Ethylene in air was supplied via a flow-through system at 4 liter·min⁻¹ and was metered using precision bore capillary tubes (300 mm of H2O pressure). The gas was supplied from a pressurized cylinder. Plants were placed in specially constructed glass-topped, gas-tight containers (360 × 910 × 460 mm high) suspended within a single growth chamber. Each container held three plants. One control (air only) and three concentrations of ethylene were used (0.01, 0.1, 1.0 μl ethylene/liter). Superimposed upon the ethylene gas treatments were three temperatures (15°, 24°, and 32°C) and three light intensities (120, 215, and 300 μmol·s⁻¹·m⁻² PAR at the top of the plant canopy, 16-hr photoperiod) in a randomized design with empty cells since only one temperature and two light intensities could be tested simultaneously within the growth chamber. Two replications of each concentration, light, and temperature combination were conducted, randomly arranged over time. Data for light treatments were pooled for statistical analysis of temperature and concentration effects due to a lack of a significant effect of light on abscission. Thus, 18 plants were examined at each concentration and temperature combination.

Plants were exposed to ethylene for 5 days since, according to preliminary experiments, the abscission response was nearly complete by this time. Following exposure, the plants were removed from the gas-tight chambers and the degree of abscission of the various plant organs recorded for each plant. Data collected included the proportion, expressed as a percentage of flower buds, fruit (subclassed based on size: <10, 10–40, 41–70, >70 mm long at the time of counting) and leaves (20–40, 41–70, >70 mm long at the time of counting) that abscised relative to the total number of each plant part present.

Silaid sprays (0.84, 2.53, and 5.07 mm) were applied to plants at randomly assigned positions along a bench in a greenhouse under the same conditions as described for their growth phase. To determine whether diurnal timing of Silaid application had an effect on abscission, plants were sprayed after sunrise (=1 hr) or just before sunset. Three plants of each treatment combination were used per replication in a completely randomized de-
sign and the experiment was replicated four times. Data are the percentage of plant parts that abscised within the 7 days following application of Silaid. Categories of plant parts monitored were as previously described. Data were collected daily; plants were agitated gently by hand and the abscised plant parts counted.

All percent abscission data were transformed to arcsine before statistical analysis; means were compared using Scheffe's simultaneous contrasts (3). Data in tables have been reconverted to percent.

Response to Ethylene Gas. Increasing the concentration of ethylene to which the plants were exposed induced a progressively greater degree of abscission (Table 1). Flower buds were highly sensitive to ethylene; the lowest concentration applied (0.01 μ-liter⁻¹) doubled abscission with respect to controls and all buds abscised at 1.0 μ-liter/ethylene-liter.

Fruit abscission was affected by fruit size. Small fruits were the most sensitive, with percent abscission decreasing with fruit maturity at a given ethylene concentration. The largest fruit and leaves abscised significantly more than the controls only at the highest concentration (1.0 μ-liter⁻¹). Temperature increases enhanced abscission in seven of the nine plant part categories (e.g., flower buds, <10 mm fruit, 10–40 mm fruit, 41–70 mm fruit, and leaves of all size categories (Table 2). Flower buds were the most sensitive to Silaid. With the application of 0.85 mM Silaid, >90% of the flower buds abscised. The abscission response of no other organ saturated at such a low concentration.

Sensitivity to Silaid decreased progressively with increasing size of the plant part (Table 2). Relatively few fully expanded leaves (>70 mm) abscised (25%) even at the highest concentration (5.07 mM). Small leaves had almost completely abscised at this concentration and medium-sized leaves (41–70 mm) responded to an intermediate degree of potential ethylene molecules from an ethylene-releasing compound is related to the number of molecules of the parent compound the organ receives, which is a function of concentration, surface area, and absorption characteristics. Leaves having large surface-to-volume ratios receive a disproportionately larger number of potential ethylene molecules than organs that have low surface-to-volume ratios (e.g., fruit, buds). Thus, leaves might be expected to have a greater susceptibility to ethylene-releasing compounds than to ethylene gas. By the same logic, larger leaves would be expected to respond more to Silaid than smaller leaves. This, however, was not the case and suggests that maturity affects sensitivity to ethylene.

Typically, immature plant parts had a distinctly greater sensitivity to both ethylene sources than more mature ones, just as in cotton (23). Maturity-related changes in sensitivity to Silaid also have been reported for young peach fruit at the time of pit hardening.

### Table 1. Effect of ethylene concentration and temperature on the percent of ethylene-mediated abscission of various organs of pepper plants, subclassed by size.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Flower buds</th>
<th>Fruit</th>
<th>Leaves</th>
<th>Pooled data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;10 mm</td>
<td>10–40 mm</td>
<td>41–70 mm</td>
<td>&gt;70 mm</td>
</tr>
<tr>
<td>Ethylene concentration (μ-liter⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>100 a</td>
<td>100 a</td>
<td>99 a</td>
<td>71 a</td>
</tr>
<tr>
<td>0.10</td>
<td>81 b</td>
<td>98 a</td>
<td>79 ab</td>
<td>25 b</td>
</tr>
<tr>
<td>0.01</td>
<td>54 c</td>
<td>90 b</td>
<td>52 b</td>
<td>14 b</td>
</tr>
<tr>
<td>0.00</td>
<td>27 d</td>
<td>74 c</td>
<td>53 b</td>
<td>11 b</td>
</tr>
</tbody>
</table>

| Temperature (°C) | | | | | | | |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 32 | 90 a | 100 a | 90 a | 31 ab | 9 b | 18 a | 10 a | 15 a | 42 a |
| 24 | 54 b | 95 b | 65 b | 39 a | 23 a | 6 b | 4 b | 5 b | 32 b |
| 18 | 66 c | 76 c | 56 b | 20 b | 22 a | 2 c | 2 b | 4 b | 23 c |

*Means are an average of 18 plants exposed to various ethylene concentrations for 5 days. Means within columns of each main effect separated by Scheffe’s simultaneous contrasts, 5% level.

### Table 2. Effect of Silaid [2-chloroethyl)methylbis(phenylmethoxy)silane] on the degree of abscission of various organs of pepper plants, subclassed by size, seven days after treatment.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Flower buds</th>
<th>Fruit</th>
<th>Leaves</th>
<th>Pooled data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;10 mm</td>
<td>10–40 mm</td>
<td>41–70 mm</td>
<td>&gt;70 mm</td>
</tr>
<tr>
<td>Concentration of Silaid (mM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.07</td>
<td>100 a</td>
<td>100 a</td>
<td>36 a</td>
<td>29 ab</td>
</tr>
<tr>
<td>2.53</td>
<td>100 a</td>
<td>99 a</td>
<td>31 a</td>
<td>66 a</td>
</tr>
<tr>
<td>0.85</td>
<td>92 a</td>
<td>78 b</td>
<td>9 a</td>
<td>9 b</td>
</tr>
<tr>
<td>0.00</td>
<td>25 b</td>
<td>37 c</td>
<td>11 a</td>
<td>10 b</td>
</tr>
</tbody>
</table>

*Means are an average of 12 plants. Means within main effects separated by Scheffe’s simultaneous contrasts, 5% level.
(11, 12, 18). In our study, the higher dose-response range (i.e., lower responsiveness) of the larger, more mature plant parts indicates that physiological changes occur as development proceeds, which renders the organ less susceptible to ethylene.

The increased abscission with elevated temperature for ethylene gas was consistent with field studies in which leaf and fruit abscission in some fruits were increased by high temperatures following application of an ethylene releasing compound (13, 24, 26, 28). Our data suggest that the effect of temperature is related to changes in the plant material sensitivity, since organs that displayed the greatest sensitivity to ethylene (i.e., flower buds and <10 mm fruit) were most strongly affected by temperature.

Our data indicate that the maximum separation of the abscission response ranges of flower buds and small fruit on one hand from those of leaves of various sizes on the other, occurs at relatively low temperatures. This relationship suggests attempts to selectively thin fruit be made on cool days or during cool parts of the day. However, it is doubtful that an application of Silaid just before cooler periods could successfully use this strategy since leaf abscission responses to gaseous ethylene-releasing compounds critically governs plant response (19, 20, 25). It has also been shown that repeated bursts of ethylene can selectively enhance fruit abscission over leaf abscission in olive (19). A greater understanding of the effect of altering ethylene concentration and duration on modification of specific plant responses is needed to allow more precise and expanded use of ethylene-releasing compounds in agriculture.

**Literature Cited**