Factors Affecting Ethephon-induced Red Color Development in Harvested Fruits of the rin Tomato Mutant

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Abstract. The effects of ethephon concentration, maturity, and length of storage before treatment on red color development were determined in harvested rin tomatoes. Red color development was greater in fruits treated with 1% ethephon than in fruits treated with higher or lower concentrations. Ethephon-induced color was greater in fruits treated 42 days from anthesis than in fruits treated at 35, 49, 56, and 63 days. Less red color developed as time in storage before treatment increased. It is suggested that ethephon (ethylene) directs red color formation in rin fruits if it is applied prior to the onset of predetermined pathways which result in the expression of the yellow color.

The rin gene has multiple effects on tomato ripening (6). Abnormal pigmentation, lack of a respiratory climacteric, reduced softening, and absence of polygalacturonase activity are examples of the pleiotropic effect of the rin gene on tomato ripening (1, 7, 8). Fruits of the rin mutant have exceptional storability and, if satisfactory red color were developed, commercial utilization of rin fruits might be possible. Eventually rin fruits turn yellow, although when normal fruits are red, rin tomatoes are still green (6). Propylene has been reported to advance the development of the yellow pigments (4), while a combination of elevated oxygen tensions and ethylene stimulated lycopene synthesis in harvested fruits (3). Red color has also been induced by treating rin fruits attached to the plant with ethephon or ethylene (5).

In preliminary observations, rin fruits usually developed red color after soaking in a solution containing 1% ethephon; however, occasionally only an enhancement of yellow color occurred. Since these inconsistencies were observed in fruits of the same genotype and growth environment, other factors were apparently contributing to the different physiological responses. The objectives of this study were to characterize ethophon-induced red color development in harvested rin fruits as influenced by stage of fruit maturation, length of storage before treatment, and concentration of ethephon.

Flowers were tagged at anthesis on field-grown plants. In all treatments described below, fruits were soaked in ethephon or water (control) for 30 min at 20°C, air-dried, and placed in storage

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at 20°C and 90 to 95% relative humidity. At least 10 fruits of a given stage of maturity were used for each treatment. Surface color was determined by a Gardner XL10 Color Difference Meter (CDM), standardized with a red tomato plate (L26.0, a28.0, and b13.3). Fruit was positioned on a 4 cm aperture one-half the distance between the blossom-end and the equatorial diam.

The effect of ethephon concn was determined by treating fruits harvested 40 days from anthesis with 0, 10, 100, 1000, 10,000, and 20,000 ppm ethephon. Color was determined after 8, 14, 23, and 30 days. A small ink mark was placed on each fruit so that the same location was evaluated each time. Fruits harvested 35, 42, 49, 56, and 63 days from anthesis were soaked in a 1% ethphon solution for 30 min to determine the effect of stage of maturation on color induction. The influence of time between harvest and treatment on color induction was determined by holding fruits harvested 40 days from anthesis at 20°C for 0, 3, 6, 9, 12, and 15 days prior to treatment with 1% ethphon. Additional samples of fruits (40 days from anthesis) were held in an atmosphere containing 22 ppm ethylene and 55% oxygen or air (control) for 3 days at 20°C. Surfacecolor was determined 15 days after treatment.

Ethephon solutions of 10 and 1000 ppm applied to rin fruits accelerated loss in greenness and increased the appearance of yellow color while 10,000 and 20,000 ppm induced red color development (Fig. 1). Maximum red color was attained by 10,000 ppm ethephon. For comparison of CDM values, normal ripen tomatoes ('Rutgers', 'H1350', and 'Campbell 36') have CDM al values of 30 to 35 (unpublished data).

Ethephon-induced red color development was greater in fruits harvested 42 days from anthesis than in fruits of other maturities (Table 1). Fruits harvested and treated 49, 56, and 63 days from anthesis developed a very slight red color. Fruits harvested 49 days from anthesis were considered to be equivalent to mature green fruits of normal cultivars (4). Therefore, fruits which were less mature than "mature green" were more responsive to ethephon-induced color development. At the time of harvest, fruits 56 days from anthesis were greenish-yellow while those 63 days from anthesis were pale yellow.

Fruits treated with ethephon or ethylene immediately after harvesting developed more red color than when held for 3 or more days prior to treatment (Table 2). The efficacy of ethephon or ethylene-oxygen treatment declined with increasing delay after harvest. Although more red color developed in the fruits treated with 1% ethephon than with atmospheres containing ethylene and elevated oxygen tension, the response to delayed treatment was parallel in both treatments.

While Mizrahi et al. (5) indicated the necessity of treating rin tomatoes attached to the plant for inducing red color, this study confirmed the results

Table 1. Effects of ethephon (1%) and stage of maturity on red surface color in rin tomatoes.

<table>
<thead>
<tr>
<th>Days from</th>
<th>Gardner CDM aL values</th>
<th>Control</th>
<th>Ethephon</th>
</tr>
</thead>
<tbody>
<tr>
<td>anthesis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>-9.28bc</td>
<td>+7.66c</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>-9.38c</td>
<td>+15.25d</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>-8.72c</td>
<td>+2.40b</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>-8.67ab</td>
<td>+.95a</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>-8.12a</td>
<td>+.42a</td>
<td></td>
</tr>
</tbody>
</table>

2 Mean separation by Duncan's multiple range test, 5% level.
The carotenoids in normal fruits are also present in *rin* fruits, although the levels in *rin* are much lower (8). Ethephon-induced red color development may be attributed to enhanced carotenoid synthesis with concomitant increased levels of lycopene. Ethephon may also be causing a shift in the carotenoid pathway to form enhanced levels of lycopene either with or without additional carotenoid synthesis. Red color appears to be formed when ethephon is applied prior to the establishment of pathways which result in the typical yellow color. The pathway of carotenoid synthesis appears to be determined and unaffected by ethephon in fruits harvested at or beyond the mature green stage and in fruits held in storage prior to treatment.

### Literature Cited


