CPPU Influences Fruit Quality, Fruit Set, Return Bloom, and Preharvest Drop of Apples

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Abstract. CPPU was applied to whole spur ‘Delicious’ apple (Malus domestica Borkh.) trees in central Washington at 0.5, 6.25, 12.5, 25, or 50 mg liter\(^{-1}\) at full bloom (FB) or FB plus 2 weeks. At both application times, the flesh firmness of treated fruit linearly increased with increasing concentration. CPPU applied at 0.5, 10, 15, or 20 mg liter\(^{-1}\) to spur ‘Delicious’ trees in Massachusetts at full bloom resulted in a linear increase in flesh firmness at harvest and following 28 weeks in air storage at 0\(\text{C}\). CPPU did not affect the incidence of senescent breakdown, decay, or cork spot. Fruit length : diameter (L/D) ratios generally increased at all doses. Fruit weight was not influenced at either location. All CPPU concentrations reduced return bloom on ‘Delicious’ apples in Massachusetts in 1989. Of the 10, 20, or 40 mg liter\(^{-1}\) treatments for ‘Empire’ apples, only CPPU at 40 mg liter\(^{-1}\) reduced return bloom. CPPU applied to ‘Empire’ apples in Massachusetts did not affect fruit set, soluble solids concentration, L/D, or firmness; however, fruit weight increased linearly with concentration. CPPU applied at 100 mg liter\(^{-1}\) retarded preharvest fruit drop of ‘Early McIntosh’ in Massachusetts for ≈7 days but was not as effective as NAA at 20 mg liter\(^{-1}\). In a larger semicommercial trial, ‘Delicious’ fruit treated with CPPU at 5, 10, or 15 mg liter\(^{-1}\) at FB, petal fall (PF), or PF plus 1 week, respectively, were harvested and graded over a commercial packing line. Malformities caused by CPPU at the highest doses reduced packout, although all CPPU application rates reduced the percent fruit culled due to poor color. CPPU increased packed fruit size, since the size of fruit (64 mm in diameter) in the >150-fruit/box size decreased, while the size of fruit (72 mm in diameter) in the 100- and 130-fruit/box sizes increased. Treated fruit stored for 7 months at 1\(\text{C}\) were firmer than nontreated controls. Chemical names used: N-(2-chloro-4-pyridyl)-1-naphthalene-acetic acid (NAA); 1 naphthalene-acetic acid (NAA).

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Effect of CPPU on 'Empire' apples in Massachusetts. Mature 'Early McIntosh'/M.7 growing at UMHRC were used in this study. Four limbs, 3.8 to 4.8 cm in diameter, per tree were selected, tagged, and all fruit counted on 1 Aug. On 2 Aug., two limbs per tree were sprayed to the drip point with CPPU at 50 or 100 mg·liter⁻¹, and a third limb was sprayed with NAA at 20 mg·liter⁻¹. All treatments included 0.05% Buffer-X. The fourth limb on each tree was not sprayed and served as the control. All fruit persisting through the same season on the tagged limbs were counted periodically, and the percent drop calculated was based on the number of fruit present on 1 Aug.

Commercial grading of 'Hi-Early Delicious' treated with CPPU in Washington. Blocks of 0.4 ha were selected from a uniform 16-ha block of 20-year-old 'Hi-Early Delicious'/seedling trees in central Washington. The soil was a sandy loam, and trees were irrigated with overhead sprinklers. Trees were treated in Spring 1990 and treatments consisted of the following: 1) nontreated control, Regulaid only; 2) Promalin at 25 mg·liter⁻¹ applied at FB; 3) CPPU at 5 mg·liter⁻¹ applied at FB; 4) CPPU at 10 mg·liter⁻¹ applied at petal fall (PF); and 5) CPPU at 15 mg·liter⁻¹ applied at PF plus 1 week. All treatments were applied to 0.4 ha of fruit with a commercial airblast sprayer. Treatments 2 and 3 were applied at a spray volume of ≈153 liters·ha⁻¹, and treatments 4 and 5 at 306 liters·ha⁻¹ to compensate for increased foliage in the canopy. Treatments were applied at ≈0600 HR in dry weather with ambient temperature between 6 and 10°C. All other commercial practices were the same for the whole block. The fruit were picked at normal commercial harvest and the bins tagged according to treatment. Fruit were placed in air storage at 0°C until they were run through a commercial packing line on 16 Dec. 1989. Cull types were determined by examining 100 fruit from the cull bin after fruit from each treatment were packed. Also, one box (20 kg) of size 100 fruit (72 mm in diameter) from each of the CPPU treatments was kept in air storage at 0°C. In April, 80 fruit per treatment were placed in a room at 20°C for 7 days before firmness testing, as previously described.

In Spring 1990, 20 limbs were selected randomly from trees in each block, their circumferences measured, and all blossom clusters counted.

Data from all replicated experiments were analyzed as a one-way analysis of variance in a randomized complete-block or completely randomized design. Means were separated by regression using SAS's General Linear Model procedure (SAS Institute, 1985) or by Duncan's multiple range test.

The large semicommercial trial was not a replicated experiment, but was designed to simulate commercial treatments. We fully realize the shortcomings of the data gathered from this endeavor and the interpretations derived therefrom. However, the data were included in an effort to substantiate results from the smaller replicated studies.

Table 1. Effect of CPPU and Promalin applied at full bloom or at full bloom plus 2 weeks on fruit characteristics of 'Oregon Spur Delicious'/MM.111 apples in Washington.

<table>
<thead>
<tr>
<th>Compound and conc (mg·liter⁻¹)</th>
<th>Fruit wt (g)</th>
<th>Flesh firmness (N)</th>
<th>Soluble solids conc (%)</th>
<th>Acidity (%)</th>
<th>L/D*</th>
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</thead>
<tbody>
<tr>
<td>CPPU</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1) 0</td>
<td>219</td>
<td>13.2</td>
<td>0.171</td>
<td>1.03</td>
<td></td>
</tr>
<tr>
<td>2) 6.25</td>
<td>214</td>
<td>13.3</td>
<td>0.170</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td>3) 12.5</td>
<td>223</td>
<td>13.7</td>
<td>0.172</td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td>4) 25.0</td>
<td>227</td>
<td>13.0</td>
<td>0.158</td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td>5) 50.0</td>
<td>216</td>
<td>13.8</td>
<td>0.161</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td>6) + GA₃,₄₅ both 12.5</td>
<td>240</td>
<td>13.9</td>
<td>0.152</td>
<td>1.08</td>
<td></td>
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<tr>
<td>Promalin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7) 25.0</td>
<td>200</td>
<td>12.9</td>
<td>0.179</td>
<td>1.06</td>
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<tr>
<td>Contrasts (significance)</td>
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<tr>
<td>Linear</td>
<td>NS</td>
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<td>NS</td>
<td>NS</td>
<td>NS</td>
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<tr>
<td>Quadratic</td>
<td>NS</td>
<td>NS</td>
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<td>Cubic</td>
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<tr>
<td>TI vs. T7</td>
<td>NS</td>
<td>*</td>
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<tr>
<td>T3 vs. T6</td>
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<td>Full bloom + 2 weeks</td>
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<tr>
<td>1) 0</td>
<td>209</td>
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<tr>
<td>2) 6.25</td>
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<td>13.9</td>
<td>0.149</td>
<td>1.03</td>
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<tr>
<td>3) 12.5</td>
<td>234</td>
<td>13.6</td>
<td>0.192</td>
<td>1.08</td>
<td></td>
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<tr>
<td>4) 25.0</td>
<td>248</td>
<td>13.9</td>
<td>0.191</td>
<td>1.05</td>
<td></td>
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<td>5) 50.0</td>
<td>223</td>
<td>13.0</td>
<td>0.180</td>
<td>1.07</td>
<td></td>
</tr>
<tr>
<td>6) + GA₃,₄₅ both 12.5</td>
<td>246</td>
<td>13.4</td>
<td>0.175</td>
<td>1.09</td>
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<tr>
<td>7) 25.0</td>
<td>225</td>
<td>13.6</td>
<td>0.173</td>
<td>1.03</td>
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<td>Contrasts (significance)</td>
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<td>NS</td>
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<td>Cubic</td>
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<tr>
<td>TI vs. T7</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
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<tr>
<td>T3 vs. T6</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
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</tbody>
</table>

L/D = Length : diameter ratio.
*Mean of 120 observations.
**Nonsignificant or significant at P = 0.05.
whereas NAA continued to retard fruit drop by 46%. No treatment affected fruit drop during the next 16 days (data not shown).

Commercial grading of 'Hi-Early Delicious' treated with CPPU in Washington. There were 25 bins (~450 kg) of fruit harvested from each treatment group. The percentage of fruit actually packed from each group was 85% for the control and Promalin treatments; 85% and 82%, respectively, for CPPU at 5 and 10 mg-liter⁻¹ and 73% for CPPU at 15 mg-liter⁻¹.

Reduced pack out at the highest CPPU concentrations was due mainly to an increase in malformed fruit frequency (Fig. 1). Fruit were classified as malformed if one side of the fruit was out of proportion or if the calyx end was uneven. Since cell division slows after anthesis, we believed that a higher concentration may be required at the later application time. However, the 15-mg-liter⁻¹ concentration was excessive. Even fruit treated with 10 mg-liter⁻¹ had 6% more deformed and misshapen fruit than the control.

CPPU treatments seemed to shift the mean fruit size to smaller fruit (Fig. 2). A Kolmorogov-Smirnov test, however, indicated no significant differences between any of the treatments and the control (data not shown). The control and Promalin treatments had the most fruit in the 80-, 88-, and >150-fruit/box sizes, whereas there were fewer fruit in the >150-, 100-, and 113-fruit/box sizes from the CPPU-treated trees. Results of blossom counts in 1990 indicated that none of the treatments influenced return bloom (data not shown).

CPPU seemed to increase the percentage of fruit surface that was red, since all CPPU treatments increased the percentage of Washington Extra Fancy fruit and reduced that of U.S. Fancy fruit (Fig. 3). Additionally, there were fewer culls due to poor color in the CPPU-treated fruit group (Fig. 1).

Fruit from air storage at 0C were evaluated in April after 7 days of storage at 20C. CPPU-treated fruit group (Fig. 1). Promalin is used commercially to elongate 'Delicious' apples. CPPU increased 'Delicious' L/D in Washington similarly to Promalin, and, in Massachusetts, CPPU was superior to Promalin. Using CPPU at concentrations of up to 15 mg-liter⁻¹ may increase L/D the most. However, reduced return bloom (Table 3) and an unacceptable high incidence of malformed fruit at harvest when using these high application rates necessitates applying CPPU at rates below 10 mg-liter⁻¹.

CPPU increased 'Empire' fruit size. This response confirms reports that CPPU increased 'Mutsu' and 'Tsugaru' (Otaga et al., 1989), 'Granny Smith' (Nickel, 1986), and 'McIntosh' (Greene, 1989) apple fruit size. Fruit size is frequently increased commercially by reducing crop load using chemical or hand thinning. CPPU can thin (Greene, 1989), but in this investigation it increased fruit size in the absence of thinning. There was, however, a tendency toward decreased fruit set. Therefore, the increase in 'Empire' fruit size must be attributed directly to the chemical. CPPU thinned 'McIntosh', but it increased fruit size so much that Greene (1989) concluded that at least part of the increased fruit size must be attributed directly to CPPU. The lack of effect of CPPU on 'Delicious' fruit size in two experiments suggests that the effect of CPPU on increasing fruit size may depend on cultivar or weather.

### Table 3. Effect of CPPU and Promalin applied in 1988 on fruit quality criteria following 28 weeks in air storage and on return bloom in 1989 of spur 'Delicious' apples in Massachusetts.

<table>
<thead>
<tr>
<th>Compound and concn (mg-liter⁻¹)</th>
<th>Flesh firmness* (N)</th>
<th>Scald* (%)</th>
<th>Blossom clusters (1989)/cm² limb cross-section*</th>
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<tbody>
<tr>
<td><strong>CPPU</strong></td>
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<tr>
<td>1) 0</td>
<td>46</td>
<td>0</td>
<td>12.0</td>
</tr>
<tr>
<td>2) 5</td>
<td>50</td>
<td>2.0</td>
<td>5.7</td>
</tr>
<tr>
<td>3) 10</td>
<td>52</td>
<td>3.7</td>
<td>1.8</td>
</tr>
<tr>
<td>4) 15</td>
<td>53</td>
<td>3.4</td>
<td>2.1</td>
</tr>
<tr>
<td>5) 20</td>
<td>54</td>
<td>6.8</td>
<td>5.6</td>
</tr>
<tr>
<td><strong>Promalin</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6) 25</td>
<td>47</td>
<td>2.4</td>
<td>7.7</td>
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<tr>
<td>Contrasts (significance)</td>
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<tr>
<td>Linear</td>
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<td>Cubic</td>
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<tr>
<td>Ti vs. T6</td>
<td>NS</td>
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<tr>
<td>T6 vs. T2 - T5</td>
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</tr>
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</table>

*Mean of 120 observations.  
**Mean of 6 observations.  
***Mean of 12 observations.  
****Nonsignificant or significant at P = 0.05.

CPPU seemed to increase red pigmentation in the commercial field trial. Sansavini (1990, personal communication) reported a similar increase in redness in 'Delicious' when CPPU was applied at 20 mg-liter⁻¹ 25 days after FB. However, Devlin and Koszanski (1998) found that anthocyanin and flavinol pigments in cranberry (Vaccinium macrocarpon Ait.) decreased following CPPU treatment, and Greene (1989) reported that red pigmentation decreased in 'McIntosh' apples receiving CPPU at 100 mg-liter⁻¹ but not 10 mg-liter⁻¹. Therefore, CPPU’s effect on color may depend on specific cultivar, concentration, and environmental conditions.

Regardless of application time, CPPU increased 'Delicious' flesh firmness. This response confirms a previous report in which CPPU increased 'McIntosh' flesh firmness (Greene, 1989). Other compounds, including butaneoic acid mono-(2,2-dimethylhydrazide) (daminozide) (Greene et al., 1977) and BA (Greene and Autio, 1989), increase flesh firmness at harvest. However, unlike fruit treated previously with daminozide or BA, flesh firmness increases caused by CPPU did not dissipate, but persisted after storage.

Greene (1989) observed at harvest that fruit treated with CPPU were difficult to separate from the spur. He suggested that CPPU may prevent preharvest drop. CPPU retarded 'Early McIntosh' apple preharvest drop in this investigation, although it was not as effective as NAA—a chemical used commercially to
retard preharvest drop should be. More frequently, cytokinins increase rather than retard abscission. BA promotes abscission of developing apple fruit (Greene and Autio, 1989; McLaughlin and Greene, 1984). N-phenyl- \( N'\)-1,2,3-thiadiazol-5-ylurea (thidiazuron), a phenylurea similar to CPPU that has cytokinin activity, promotes leaf abscission in cotton (Gossypium hirsutum L.) (Suttle, 1985).

Luckwill (1969) first suggested that cytokinins may stimulate flower bud formation in fruit spurs. The cytokinins that have been reported to increase flower bud formation are \( N'\)-substituted purines and not phenylurea compounds like CPPU. Greene and Autio (1989), Greene et al. (1990), and McLaughlin and Greene (1984) have confirmed that BA increases flower bud formation in apples. In this study, CPPU inhibited 'Empire' flower bud formation. This result confirms an earlier report that CPPU also inhibited 'McIntosh' return bloom (Greene, 1989).

**Literature Cited**


controlled. Bougainvillea flowering is pro-
glabra Bougainvillea × buttiana
North Florida Research and Education Center, University of Florida, Institute
Northern Research and Education Center, University of Florida, Institute
temperatures (27.5-32°C) and two production seasons (late spring to early summer and

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for publication 14 Sept. 1992. Florida Agriculture

ous nature. Plants need to be pinched or pruned
during hanging basket production of 'Barbara Karst'. Chemical name used: sodium salt
enhanced flowering compared with controls during midspring to early summer, but it did

more flowers than that of controls (pruned only at 0 and 4 weeks), with 'Barbara Karst'
midsummer to early fall). During the late production season, liners pruned at transplanting

of Food and Agricultural Sciences, Monticello, FL 32344

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The use of dikegulac foliar sprays in production of 4.5-liter hanging baskets (25.4-

Humb. & Bonpl.) 'Barbara Karst' and 'Rain-

Joiner et al., 1962). Using dikegulac to im-

dikegulac-sodium, growth regulator, branching, chemical pinching,

growth habit (Norcini et al., 1992). However, upright shoots

were more easily
detracted from the overall appearance of some


tion was markedly enhanced when 1200 mg
dikegulac/liter at 4 weeks (or 600 mg

can be labor intensive due to the plant's vigor-

if growth and flowering were more easily

the structure-

activity relationship. Chem. Pharmaceutical


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