NAA THINNING OF ‘MURCOTT’:
COMPARISON OF SMALL PLOT AND COMMERCIAL HARVEST DATA

ED STOVER1, SCOTT CILIENTO, AND MARK RITENOUR
University of Florida, IFAS
Indian River Research and Education Center
2199 S. Rock Road
Ft. Pierce, FL 34945

CHARLES COUNTER
Haines City Citrus Growers Association
Bannon Island Road
Haines City, FL 33844

Additional index words. auxin, chemical thinning, Citrus reticulata, cropload control, mandarin, naphthaleneacetic acid, tangerine, tangor

Abstract. NAA thinning of ‘Murcott’ was evaluated in four groves near Haines City, Florida using a randomized complete block design with entire rows as experimental units. Groves studied were: 4-, 8-, and 20-yr old ‘Murcott’ (Citrus reticulata Blanco hybrid) on Cleopatra mandarin (C. reticulata Blanco) rootstock, and ‘Murcott’ topworked onto ‘Ambersweet’ [(C. reticulata Blanco × C. paradisi Macf.) × (C. reticulata Blanco) × midseason orange [C. sinensis (L.) Osb.]] on Cleopatra mandarin rootstock in 1999. Treatments were applied 15 May 2001 during early physiological drop, when mean fruitlet diameter was already 0.87-0.95 inches (22-24 mm) with 2-20% of sampled fruitlets less than 20 mm (0.79 inches), and mean cropload was moderately high at 6-8 fruitlets per ft² of canopy (64-88 m²). NAA was applied at 250 and 350 ppm plus 0.05% nonionic surfactant, using an airblast sprayer at 60-100 gpa (560-935 L-ha⁻¹). Fruit were harvested January 2002 with small plot data collected (2 trees per row) on 3 of the 4 groves and packinghouse data (all trees combined within each treatment per grove) on two of these groves and one additional grove. NAA increased fruit size in all experiments with little difference between the two rates. Small plot data showed that NAA increased mean fruit weight by 25-34%, decreased fruit per tree by 24-38%, and decreased fruit yield per tree by 4-24%. Packinghouse data were consistent with small plot results: NAA increased production of 64-100 count fruit by 59-100%, even though no fruit were eliminated because of small size in non-thinned controls. In two of the pack-

This research was supported by the Florida Agricultural Experiment Station, and approved for publication as Journal Series No. R-08906.

1Corresponding author.

Many fruits, including some citrus cultivars, have a strong tendency for alternate bearing, a condition where trees produce very heavy crops of small fruit in the “on” year and much smaller crops of larger fruit in the “off” year (Monselise and Goldschmidt, 1982). Alternate bearing often reduces cumulative value of the fruit produced, since many fruit in the “on” year may be smaller than accepted market sizes or be sorted into smaller market categories which receive lower unit prices. In addition, trees may be stressed by the heavy demands of fruit production in the “on” year, substantially reducing growth of younger trees or even breaking many limbs, which are likely to compromise future production.

Early reduction of croploads in the “on” year can reduce alternate bearing and often increase fruit size. Chemical thinning agents are routinely used for this purpose in commercial apple (Malus × domestica Borkh.) (Forshey, 1986) and pear production (Pyrus communis L.) (Stover et al., 1995), while hand thinning is the standard practice in most stone fruits [Prunus species] (Southwick and Glozer, 2000). Florida citrus producers have primarily relied on hedging, topping, and/orisking to reduce cropping in groves with excessive bearing (Stover et al., 2003), but increased production of larger fruit is often modest despite substantial cropload reductions (Morales and Davies, 2000). In addition, pruning for cropload reduction is likely to delay canopy development in young groves (Stover et al., 2003). For these reasons, many researchers have assessed potential chemical thinners for use on citrus (Brar et al., 1992; Farmahan, 1992; Greenberg et al., 1992; Harty and Sutton, 1994; Hutton, 1992; Sharma et al., 1993; Wheaton, 1981).

The synthetic auxin naphthalene acetic acid (NAA) is a widely used chemical thinning agent that has been demonstrated to thin citrus in Florida (Wheaton and Stewart, 1973) and is currently registered for use in Florida on oranges, tangerines, tangors, and tangelos (Stover et al., 2002). However,
Florida agricultural chemical dealers indicate that NAA is seldom used in commercial Florida citrus production (personal communication). We have seen significant increases in fruit size in nine of ten NAA thinning trials conducted on Florida ‘Sunburst’ and ‘Murcott’, and have demonstrated effective response when applied using airblast applications at volumes of 67-250 gpa (630-2340 L ha⁻¹; Stover et al., 2001a). This trial was conducted to demonstrate: 1) the validity of small plot experimental data for evaluating commercial scale harvests; and 2) the value of NAA thinning in Florida ‘Murcott’.

**Materials and Methods**

**Trees used in this study.** NAA thinning of ‘Murcott’ tangerine was evaluated in four groves near Haines City, Florida (Table 1). The experiment was conducted using a randomized complete block design with entire rows as experimental units and three experimental units per treatment in each grove. ‘Murcott’ groves used were 4-, 8-, and 20-yr old trees on Cleopatra mandarin rootstock, and ‘Murcott’ topworked two years prior to treatments onto ‘Ambersweet’ on Cleopatra mandarin rootstock. All trees were planted on Candler fine sand soil (hyperthermic Typic Quartzipsamments), were microsprinkler irrigated, and received routine care for commercial production of fresh ‘Murcott’.

**NAA applications.** Treatments were applied 17 May 2001 during early physiological drop. Mean fruitlet diameter was already 0.87-0.95 inches (22-24 mm) with 2-20% of sampled fruitlets less than 0.79 inches (20 mm), and mean cropload moderately high with 6-8 fruitlets per ft² of canopy (64-88 m²). NAA was applied at 250 and 350 ppm NAA (Fruitfix K-Salt 800, AmVac Chemicals, Long Beach, Calif.) plus 0.05% non-ionic surfactant (Diamond-R Activator™, 80% alkylarylpolyoxyethylene glycols-isopropanol), using an airblast sprayer (Rear’s MFG. Co. Eugene, Ore.) at 60-100 gpa (560-935 L ha⁻¹). No rain was recorded for 3 d prior to application or 5 d following treatments, with high temperatures of 90-95 °F (32-35 °C) throughout this period. Microsprinkler irrigation was maintained at 60 gal per tree (230 L per tree) applied three times per week.

**Harvest data.** Trees were strip-harvested Jan. 2002. The grower cooperated was forced to harvest one grove (8-yr old trees) before we could be notified. As a result, packinghouse data but not small plot data were obtained from this site. Mite damage was deemed unacceptable from the grove of ‘Murcott’ topworked onto ‘Ambersweet’, consequently no packinghouse data were obtained from this site. Therefore, small plot data were collected from three of the four groves and packinghouse data (all trees combined within each treatment per grove) were collected from two of these groves and the one grove on which small plot data were not obtained.

For the small plot data, two typical trees within each treated row were harvested, selecting within the third through tenth trees from the northmost end of each row. All fruit from individual data trees were counted, and total fruit weight per tree was calculated by determining net fruit weight from each field box. A 50-fruitlet random sample was collected from each data tree, with diameter and mass determined for each fruitlet, and standard deviations calculated for fruit diameter and mass for each tree.

Estimates of fruit size distribution were determined from the mean fruit size and standard deviation data, and net return for each size class was calculated from costs and carton price data provided by the packinghouse using the method described in Stover et al. (2001b). Costs per carton included picking, roadsiding, hauling, drenching, packing, stickering, marketing costs, and taxes. NAA application costs were subtracted from returns calculated from small plot data and actual returns provided by the packinghouse. All costs and returns are listed in Table 2. For comparison to commercial harvest data, information from each small-plot tree was multiplied by trees per acre (Table 1). Number of fruit per tree, mean fruit weight, total boxes per acre, projected cartons per acre in each size class, and projected net return per acre were the parameters analyzed for each tree. Data were subjected to ANOVA with rows as experimental units and individual trees as samples. For Grove A, means were separated using DMRT. For Groves B and C, contrast analyses were conducted between non-treated controls and the two NAA treatments, with probability of significant difference indicated for each contrast presented.

Commercial scale harvests were conducted by separately harvesting each treatment within a grove, with strip-picking of all trees and all replications combined. Boxes per acre were calculated and fruit identity was maintained through the packinghouse to collect mean packout data for each treatment in each of three groves. No statistical analysis is possible on these data, but are presented for comparison to small plot data.

In Grove D (where only commercial packout data were collected) hedging, topping, and skirting for fruit size enhancement were conducted in late Mar. 2001, in lieu of NAA thinning, on several rows adjoining our replicated trials. Fruit from these trees were completely harvested and handled along with the fruit from the NAA thinning experiment. Although no statistical comparisons are possible, we conclude that these data are sufficiently interesting to warrant inclusion in this manuscript.

**Results and Discussion**

**Small Plot Data.** Thinning response following NAA treatment was marked and consistent. Fruitlet diameter at applica-

---

**Table 1. Summary of Murcott groves used in this study. All trees were grown on Candler sand in Haines City, Fla., irrigated using microsprinklers, and were managed for fresh fruit production.**

<table>
<thead>
<tr>
<th>Grove identification</th>
<th>Grove planted in:</th>
<th>Rootstock</th>
<th>Trees/acre¹</th>
<th>Results sown in:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grove A</td>
<td>1995 (topworked 1999)</td>
<td>Ambersweet / Cleo</td>
<td>120</td>
<td>Table 3 (no packinghouse data)</td>
</tr>
<tr>
<td>Grove B</td>
<td>1997</td>
<td>Cleo</td>
<td>139</td>
<td>Table 4</td>
</tr>
<tr>
<td>Grove C</td>
<td>before 1987 (year unknown)</td>
<td>Cleo</td>
<td>116</td>
<td>Table 5</td>
</tr>
<tr>
<td>Grove D</td>
<td>1993</td>
<td>Cleo</td>
<td>116</td>
<td>Table 6 (no small plot data)</td>
</tr>
</tbody>
</table>

¹Multiply trees per acre by 2.47 to generate trees per ha.
tion was larger than the commonly recommended 0.39-0.59 inches (10-15 mm) range, but was within the physiological drop period recommended by Wheaton (1981) for Florida mandarins. Across the three groves where small plot data were collected, number of fruit per tree was decreased by 24-38% (mean 32.6%) and mean individual fruit weight was increased by 25-34% (mean 28.7%). Increase in fruit size largely compensated for NAA-induced reduction in numbers of fruit per tree. Although boxes per acre were numerically decreased by 4-24% in the three plots (mean 13.6%), contrasts between NAA and control were significant at p ≤ 0.05 in only one of these experiments (Grove B, Table 4). Estimated cartons (28 liter cartons = 4/5 bushel) of 64 to 100 count fruit, calculated using the method of Stover et al. (2001b), indicated substantial increases from NAA treatment in all three experiments with small plot data. Estimated increases were 5.4 fold (Grove A, Table 5), 2.0 fold (Grove B, Table 4), and 2.0 fold (Grove C, Table 5) for the three experiments. Decreases in small size fruit were also substantial (data shown for only one experiment, Table 3). Even though fruit size was markedly enhanced, projected returns per ha were significantly greater following NAA treatment in only one of three experiments compared to controls (Table 3).

In no case was there any significant difference between the 250 and 350 ppm NAA rates for any parameter measured. Separate results for the two rates are presented for only two groves (Tables 3 and 6) with a combined mean response for NAA treatment presented for the two groves with both small plot and packinghouse data (Tables 4 and 5).

### Packinghouse data
Packinghouse data on yield were consistent with small plot results and indicated that NAA increased production per acre of 64-100 count fruit by 59-100% (Tables 4-6). This increase in production of larger fruit following NAA thinning occurred even though no undersize fruit were produced on non-thinned control trees. In two of the packinghouse assessments, NAA treatments increased packout by 10% of total harvested crop (Tables 4 and 6), through better color and fewer scars on the NAA thinned fruit (data not shown). Packinghouse reports on crop value following NAA treatment were: a loss of $326 per acre (US$805/ha; a 9% loss, Table 4); an increase of $588 per acre (US$1452/ha; an 11% gain, Table 5); and an increase of $50 to 410 per acre (US$124-1015/ha; a 1-7% gain, Table 6). Because yield and crop value are so variable, none of these differences exceed the LSD calculated for the small plot data (data not shown) and it would be inappropriate to conclude that they represent real differences resulting from treatment effects. Therefore, no clear NAA effect on crop value was apparent in the cropping year in which NAA was applied.

In the grove where no small plot data were collected (Table 6), it is intriguing that pruning intended to enhance fruit size resulted in fruit size and percent packout that were virtually identical to controls, and pruned trees provided $1500 less net return per acre (US$3211/ha) than controls, even without including pruning costs. Response to NAA in this grove was numerically similar to that observed in groves described in Tables 3-5. While no conclusions can be drawn from these data, they may have value in stimulating further experimentation.

### Table 2. Data used in calculating crop value. Values of fruit and costs were obtained from the packinghouse where these fruit were handled. Costs included harvesting, hauling, roadising, drenching, packing, stickering, marketing, and taxes.

<table>
<thead>
<tr>
<th>Fruit per 4/5 bushel carton</th>
<th>Minimum fruit diam. (mm)</th>
<th>Minimum fruit wt. (g)</th>
<th>FOB price/packed carton ($)</th>
<th>Costs/packed carton ($)</th>
<th>Return/carton ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64s</td>
<td>87</td>
<td>261</td>
<td>18</td>
<td>6.95</td>
<td>11.07</td>
</tr>
<tr>
<td>80s</td>
<td>81</td>
<td>222</td>
<td>18</td>
<td>6.95</td>
<td>11.07</td>
</tr>
<tr>
<td>100s</td>
<td>75</td>
<td>182</td>
<td>16</td>
<td>6.95</td>
<td>9.07</td>
</tr>
<tr>
<td>120s</td>
<td>68</td>
<td>143</td>
<td>14</td>
<td>6.95</td>
<td>7.07</td>
</tr>
<tr>
<td>150s</td>
<td>64</td>
<td>113</td>
<td>12</td>
<td>6.95</td>
<td>5.07</td>
</tr>
<tr>
<td>176s</td>
<td>60</td>
<td>93</td>
<td>10</td>
<td>6.95</td>
<td>3.07</td>
</tr>
</tbody>
</table>

1) Eliminations represented a mean loss of $4.52 per box from harvesting through hauling for disposal. There was no juice market for these fruit in this year.
2) NAA application cost: $19.16 per acre ($47.32/ha) at 100 gpa (935 L·ha⁻¹) (Muraro and Still, 2001).
3) NAA and surfactant costs / 100 gallons (380 L): $95.38 at 350 ppm $73.82 at 250 ppm.
4) 4/5 bushel = 28 L.
5) Divide by 25.4 to convert mm into inches.
6) Divide by 28.4 to convert g into oz.
7) 4/5 bushel = 28 L.
8) Multiply by 2.47 to convert units ha⁻¹ into units·ha⁻¹.
9) Divide by 28.4 to convert g into oz.
10) Potential return with no elimination based on size or appearance.
11) Projects of cartons in size classes and return per acre and based on method of Stover et al. 2001b.

### Table 3. Effect of 17 May 2001 NAA treatment on Murcott cropload, fruit size, yield, and crop value at harvest in Jan. 2002. Grove A: trees were topworked in 1999 onto Ambersweet with Cleopatra rootstock in Haines City, Fla.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fruit/ tree</th>
<th>Mean fruit size (g)</th>
<th>Standard deviation fruit size</th>
<th>Total boxes/acre</th>
<th>64-100 count</th>
<th>64-150 count</th>
<th>176 – too small count</th>
<th>Projected net return/acre ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>827 a</td>
<td>142 b</td>
<td>26.4</td>
<td>323 a</td>
<td>76 b</td>
<td>638 a</td>
<td>94 a</td>
<td>3700 b</td>
</tr>
<tr>
<td>250ppm NAA</td>
<td>518 b</td>
<td>191 a</td>
<td>26.2</td>
<td>275 a</td>
<td>416 a</td>
<td>692 a</td>
<td>0 b</td>
<td>4080 a</td>
</tr>
<tr>
<td>350ppm NAA</td>
<td>547 b</td>
<td>188 a</td>
<td>27.8</td>
<td>285 a</td>
<td>404 a</td>
<td>616 a</td>
<td>0 b</td>
<td>4740 a</td>
</tr>
</tbody>
</table>

1) Multiplying within columns by Duncan’s multiple range test, 5% level.
2) Multiply by 2.47 to convert units acre⁻¹ into units·ha⁻¹. Divide by 28.4 to convert g into oz.
3) Cartons are 28 L = 4/5 bu.
4) Projections of cartons in size classes and return per acre and based on method of Stover et al. 2001b.
5) Potential return with no elimination based on size or appearance.

Comparison of small plot and commercial data. Many Florida citrus growers express skepticism that small plot data are representative of responses likely on a commercial scale. We hope that these data will increase grower confidence, since harvest of six trees per treatment in small plots vs. hundreds of trees per treatment in commercial harvests provided similar results. In grove B (Table 4), packinghouse data indicated that NAA reduced boxes per acre by 32% vs. 24% in small plot data. Both data sets indicated that NAA substantially increased production of 64-100 count fruit, while decreasing production of fruit across 64-150 count sizes. Modest numerical differences for economic returns were not statistically significant in the small plot data and reflected high variability in crop value per tree. Similarly, in grove C, packinghouse and small plot data indicate no effect of treatment on boxes per acre or net return but that production of 64-100 count fruit was doubled on trees treated with NAA.

Cumulative value of thinning. It is notable that thinning with NAA did not markedly increase crop value in most of these trials, even though production of large size fruit was substantially enhanced. None of the trees in this trial was sufficiently overcropped to result in branch breakage or elimination of fruit for small size. Increase in production of larger fruit without increasing crop value has been observed in many of the NAA thinning trials conducted on Florida citrus (Stover et al., 2001a).

NAA thinned trees were observed to have a much stronger summer flush than nonthinned trees and appeared to be...
less stressed throughout the fall and winter (data not shown). Improved return cropping was apparent on NAA thinned trees in the following spring (year 2002, data not shown), with many nonthinned trees bearing little fruit, and especially poor cropping in the nonthinned trees of the topworked grove. Across all four groves, trees thinned with NAA in the previous year appeared to have a moderate crop, which was expected to have optimal development without any need for subsequent thinning. Better return cropping in the “off-year”, combined with improved young tree development, appear to have substantially increase cumulative two-year returns following NAA thinning. Commercial scale harvests of groves B, C, and D in Jan 2003 were conducted as in 2002, and trees thinned with NAA in 2001 had markedly higher yields than controls in each grove (5.2X in Grove B, 1.7X in ‘Grove C, 4.4X in Grove D).

Table 6. Effect of NAA treatment 17 Mar 2001, and hedging/topping/skirting late Mar. 2001 on Murcott fruit size distribution, yield, and crop value at harvest in Jan 2002. Grove D: trees were planted on Cleopatra rootstock in 1995 in Haines City, Fla. Data from commercial harvest of 250 trees per treatment. NAA and control treatments were replicated but combined in harvest, permitting no assessment of variability between replications.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Boxes/acre¹</th>
<th>Percent packout²</th>
<th>Net return/acre² ($</th>
<th>64-100 count</th>
<th>64-150 count</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>513</td>
<td>73</td>
<td>5941</td>
<td>352</td>
<td>748</td>
</tr>
<tr>
<td>250ppm</td>
<td>384</td>
<td>83</td>
<td>5990</td>
<td>592</td>
<td>638</td>
</tr>
<tr>
<td>350ppm</td>
<td>405</td>
<td>82</td>
<td>6351</td>
<td>578</td>
<td>664</td>
</tr>
<tr>
<td>hedge/top/skirt³</td>
<td>430</td>
<td>71</td>
<td>4622</td>
<td>286</td>
<td>616</td>
</tr>
</tbody>
</table>

¹Hedged 6-10 inches (15-25 cm) off each side, topped 18 inches (46 cm), and skirted in late Mar. 2001: in adjoining area of same grove but not within replicated area. Cost of pruning not included in calculating returns.
²Multiply by 2.47 to convert units·acre⁻¹ into units·ha⁻¹.
³All elimination from fresh pack resulted from poor color and blemish, no rejection for small size.
*Cartons are 28 L = 4/5 bu.

Literature Cited


