Antitranspirant and Root and Canopy Pruning Effects on Mechanically Transplanted Eight-year-old ‘Murcott’ Citrus Trees

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Abstract. Two groups of 8-year-old ‘Murcott’ [Citrus reticulata Blanco × C. sinensis (L.) Osbeck hybrid?] trees on rough lemon (C. jambhiri Lush.) rootstock were transplanted with a Vermeer tree digger in March and July, respectively. Root and shoot pruning and a 2% (v/v) spray of a pinolene-based antitranspirant (Vapor Gard) formed the treatments either individually or in combination. Canopy size at transplanting had the greatest effect on tree water-stress and subsequent tree growth and yield. The antitranspirant and root pruning tended to reduce leaf water-stress, but the effects generally were small and nonsignificant. Root pruning also seemed to stimulate new root growth. After transplanting, roots grew 2 to 3 m beyond the soil ball in one year. Four years after transplanting there were virtually no differences in tree height or canopy volume. Cumulative yield was less for trees with 30% and 85% of their foliage removed as compared to those with 50% removed. Trees pruned 50% bore fruit the year after transplanting and consistently yielded more throughout the study.

Tree replacement often is required in a citrus orchard because of losses from various factors. The economic impact of this replacement varies with the number of trees being replaced (11) and their age at the time of replacement. The loss in orchard yield potential is considerably greater when a tree in an old orchard is replaced with a conventional nursery tree than a similar replacement in a young, nonfruiting orchard. Thus, minimizing the disparity in age and production level between the original trees in an orchard and their replacements is of interest to growers.

One approach to this situation has been to fill an orchard vacancy with a mechanically transplanted fruiting tree, generally about 3 to 10 years in age. In moving such trees, attention is focused usually on the prevention of a level of water stress which may hinder tree recovery or result in the tree failing to survive transplanting. The methods involved have included antitranspirant application and canopy pruning. Seven-year-old navel orange trees in California were transplanted with a Vermeer tree digger after 20% of the canopy was removed (8). Several antitranspirants were studied in order to reduce "transplant shock" which was defined as the point where "water loss from leaves exceeds uptake through a damaged root system" (8). Leaf xylem tension was lower in those trees receiving an antitranspirant; however, any long-term effects were not determined. Furthermore, the water stress of trees 10 days after transplanting was still greater than that of undisturbed trees. This suggests that although the antitranspirants provided some advantage, a greater canopy reduction prior to transplanting may have proved more beneficial.

Florida growers occasionally mechanically transplant 6- to 10-year-old fruiting trees. "Transplant shock" is avoided largely by manipulating canopy size rather than by using antitranspirants which have been explored only experimentally in Florida (1, 2).

The fruiting trees used for transplanting normally have a well-developed, extensive root system in Florida's sandy soils (5, 9); however, many roots are severed during transplanting. It has been proposed that posttransplant water stress and the resultant effects on growth can be reduced or avoided if the surface area for water uptake balances the transpiration surface area (3). Therefore, it is customary to prepare trees for transplanting by cutting back the canopy to the major limbs (buckhorning) which removes 80% or more of the foliage. Supposedly, the portion of the root system transplanted then would be more than adequate to supply water to the reduced canopy. Any unnecessary pruning of the canopy, though, is undesirable and inconsistent with the primary purpose of using a fruiting tree for resetting in an orchard. The degree of canopy pruning may have longlasting effects on tree performance. The objective of this study was to compare the effects of a commercial severe canopy pruning practice with 2 less severe pruning treatments, and root pruning, on tree water-stress and the subsequent regrowth and yield of mechanically transplanted citrus trees. In addition, these treatments were combined with the use of an antitranspirant to determine their influence on tree water-stress.

Materials and Methods

The trees used in this experiment were part of an 8-year-old 'Murcott' orchard on rough lemon rootstock located in southern central Florida near Avon Park. The soil is Blanton fine sand. The rooting depth is about 1.5 m; however, drainage ditches are required to prevent the water table from periodically rising and damaging roots.

'Murcott' trees are subject to severe alternate bearing to the extent that heavily fruited trees may collapse, a disorder known as 'Murcott' Decline (13). Such trees often exhibit dieback of branches to various degrees. The trees used here, however, have fruited regularly and evenly. Any effects on this study from this cropping characteristic were considered minimal.

The trees, originally spaced 2.7 × 6.7 m, had started to develop into hedgerows. The grower decided to remove alternate
trees in each row to use as replacements in another nearby ‘Murcott’ planting in which the trees were spaced 5.4 × 6.7 m.

Two experiments were conducted using apparently healthy trees selected for their uniformity in canopy diameter (about 2.5 m) measured between rows, and height (about 2.6 to 3.8 m). The canopy pruning treatments were applied 72 hr before transplanting. The antitranspirant, Vapor Gard, a polyterpene (1), was then applied as a 2% (v/v) aqueous solution as appropriate (Table 1). Tree canopy pruning was gauged subjectively as the reduction in the amount of foliage achieved by a hedging type of pruning. The resulting trees were generally reduced in height and width. Lower limbs sometimes were entirely removed to provide access for the transplanting equipment.

The trees were moved about 400 m with a truck-mounted Vermeer tree digger. This hydraulically operated, 4-bladed device cleanly severed all roots while removing a conical soil mass about 1.1 m in diameter and depth. The trees were transferred by replicate to the receiving site and deposited according to a randomized complete-block design. The trees, in most instances, were not adjacent to each other but were located in areas designated as replicates which included other already established trees. Normally, transplanted trees would be irrigated immediately; however, the experiment trees were not watered for 7 days after transplanting in order to observe any visible signs of treatment effects on water stress. Thereafter, they were maintained on the cultural program of the surrounding orchard.

The treatments for each experiment are described in Table 1. Also, 5 additional trees were root-pruned with the digger and left in place for 4 months. The day following the transplanting of the expt. 2 trees in July, the extra root-pruned trees and 5 unpruned trees were removed with the digger, set on the ground, and the soil washed from the root ball. The root system of each of the 10 trees was then evaluated for apparent fibrous root quantity.

Leaf water-stress was estimated by measuring leaf xylem tension prior to transplanting and, periodically thereafter, using the pressure-chamber technique (12). Leaf xylem tensions are given as positive values so that larger, absolute values are equivalent to greater water stress. Data were collected by replicates using 4 shaded, mature leaves per tree, one from each quadrant of the canopy. Only 4 replicates were used which kept the measurement time to about 1 hr. Treatment SP was excluded because there were virtually no leaves available which could be used for comparison with the other treatments. Ambient air temperature and relative humidity were determined during each measurement period with a sling psychrometer.

Canopy height and width were measured annually through 1982. Canopy volume was calculated using the equation for one-half of a prolate spheroid (16), \[ V = 0.5236 \, H \, D^2 \] where \( V \) = volume, \( H \) = canopy height, and \( D \) = canopy diameter. Yield was estimated annually on the basis of the standard Florida box which is equivalent to 43 kg of fruit. This procedure was considered satisfactory for making treatment comparisons. The amount of fruit/tree was small enough to be easily estimated, and the differences between treatments were often larger than the variation within a treatment. Data were tested for significant differences using an analysis of variance with mean separation by Duncan’s multiple range test.

Results and Discussion

The trees used in expt. 1 were transplanted on a cloudless day in March. Five cm of rain had fallen at the site in the week preceding the start of the experiment. During the day of transplanting, the trees were not unusually water-stressed. Leaf xylem tension did not increase above 15.5 bars, a value not uncommon for undisturbed citrus trees in Florida (6, 7, 14, 15). The differences between treatments were small, usually less than 2 bars (Table 2).

### Table 1. Description of treatments and environmental conditions on the day of transplanting.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Date and environ. cond.</th>
<th>No. of replications</th>
<th>Treatment symbol</th>
<th>Description</th>
</tr>
</thead>
</table>
| 1          | March 1978  
**Air temperature**  
15°C to 23°C  
*Relative humidity*  
55–69% | 5 | SP | Severely pruned with 80% or more of the foliage removed; no antitranspirant. (Normal commercial practice.) |
|            |  | | 50 P | 50% of the foliage removed; no antitranspirant. |
|            |  | | 50 AT | Same as 50 P except antitranspirant applied. |
|            |  | | 30 AT | 30% of the foliage removed with antitranspirant applied. |
| 2          | July 1978  
**Air temperature**  
29° to 35°C  
*Relative humidity*  
79–85% | 4 | SP | Same treatment as described above. |
|            |  | | 50P | Same treatment as described above. |
|            |  | | 50 AT | Same treatment as described above. |
|            |  | | 50 PR | 50% of the foliage removed; no antitranspirant; root-pruned in March and left undisturbed until July. |
|            |  | | 50 ATR | 50% of the foliage removed; antitranspirant applied; root-pruned in March and left undisturbed until July. |

*Single-tree plots.
The high soil water content, combined with the use of shade leaves to measure leaf xylem tension, may have contributed to masking any real treatment effects. Nevertheless, the treatment differences were consistent and canopy pruning seemed to have a greater effect on tree water-stress immediately after transplanting than antitranspirant use. It initially appeared that the antitranspirant compensated for the 20% difference in foliage when comparing the 30 AT and 50 P treatments; however, the 30 AT trees had the greatest xylem tensions throughout the day. In addition, these trees wilted and began to shed leaves soon after transplanting. The antitranspirant also failed to influence the leaf xylem tension of the trees with a similar amount of foliage (50 P-50 AT). The leaves on these trees appeared turgid throughout transplanting and displayed no visible signs of water stress thereafter.

In the July experiment, all trees had one-half of their foliage removed and root pruning (50 PR) was an additional treatment. Also, it was warmer and more humid on the day of transplanting than in March (Table 1), and no rain had fallen for at least 7 days prior to transplanting. When the trees were moved, there were no differences in leaf xylem tension (Table 2). After transplanting, leaf xylem tension was again unaffected by the antitranspirant or root pruning; however, these treatments when combined (50 ATR), significantly decreased leaf xylem tension by about 6 bars, as compared to the 50 P trees.

The root-pruned trees appeared to have about 20–25% more fibrous roots than the unpruned trees; however, this difference probably was not as meaningful in the state of root activity. Root pruning seemed to stimulate the growth of roots already present, and to a lesser extent, the development of new roots (Fig. 1). Growing roots enhance water uptake (10) and their greater root activity of the 50 PR trees may account for their consistently lower leaf xylem tensions as compared to the 50 P trees.

New roots did develop on the distal ends of roots cut during pruning, but most of these were severed during transplanting (Fig. 1). After transplanting, the root system expanded rapidly. Lateral roots had extended 2 to 3 m beyond the edge of the soil ball within one year. Thus, any benefit derived from root pruning was probably brief.

The main objective of this study was to compare the canopy regrowth and yield of the trees for several years posttransplant. Only canopy size had any effect on long-term tree performance. The trees in the March experiment were approaching their original size after 4 years, and their productivity had increased from less than 40 kg/tree to over 80 kg/tree (Table 3). Data for the July trees are not presented because they were all foliage-pruned 50% and responded in the same manner as the 50 P and 50 AT March trees.

The severely pruned (SP) trees, which were reduced in height to 1.3 m, gradually recovered their original size, but at the expense of a marked reduction in productivity as shown in their cumulative yield (Table 3). They were bush-like in appearance from vigorous new growth as soon as 6 months after transplanting (Fig. 2). After 4 years, they were about the same size and as productive as the 50 P and 50 AT trees; however, the SP

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Table 2. Effect of shoot- and root-pruning and Vapor Gard antitranspirant on the leaf water status of mechanically transplanted, 8-year-old ‘Murcott’ trees on rough lemon rootstock.

<table>
<thead>
<tr>
<th>Date and experiment</th>
<th>Time (HR)</th>
<th>30 AT</th>
<th>50 P</th>
<th>Treatment</th>
<th>30 AT</th>
<th>50 PR</th>
<th>50 ATR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expt. 1, March</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretransplant</td>
<td>0830</td>
<td>6.9 b</td>
<td>8.1 a</td>
<td>6.3 b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immed. posttranspl.</td>
<td>1030</td>
<td>13.8 a</td>
<td>12.9 ab</td>
<td>12.6 b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1400</td>
<td>15.5 a</td>
<td>15.3 ab</td>
<td>14.6 b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1600</td>
<td>11.3 a</td>
<td>8.2 c</td>
<td>9.9 b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expt. 2, July</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretransplant</td>
<td>0900</td>
<td>10.7 ns</td>
<td>9.6</td>
<td>8.7</td>
<td>7.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immed. posttranspl.</td>
<td>1130</td>
<td>18.7 a</td>
<td>14.4 ab</td>
<td>13.7 ab</td>
<td>12.2 b</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1500</td>
<td>23.0 a</td>
<td>19.2 ab</td>
<td>20.4 ab</td>
<td>16.8 b</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1800</td>
<td>21.4 a</td>
<td>16.8 ab</td>
<td>16.5 ab</td>
<td>13.9 b</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Mean of 4 replications. See Table 1 for explanation of the treatment symbols.

Table 3. Yield and growth response of mechanically transplanted, 8-year-old ‘Murcott’ trees on rough lemon rootstock.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Tree height (m)</th>
<th>Canopy vol (m³)</th>
<th>Yield (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP³</td>
<td>1.3 c</td>
<td>2.7 ns</td>
<td>---</td>
</tr>
<tr>
<td>30 AT</td>
<td>2.7 a</td>
<td>3.0</td>
<td>5.1 a</td>
</tr>
<tr>
<td>50 P</td>
<td>2.3 b</td>
<td>2.8</td>
<td>2.7 b</td>
</tr>
<tr>
<td>50 AT</td>
<td>2.3 b</td>
<td>2.7</td>
<td>2.7 b</td>
</tr>
</tbody>
</table>

³Data obtained from 5 replications of expt. 1.

²See Table 1 for explanation of treatment symbols.

³Mean separation in columns by Duncan's multiple range test, 5% level; ns = nonsignificant.
trees produced very little fruit in the first 2 years. Also, the fruit was produced on vigorous shoots and tended to have a relatively coarse, thick rind similar to fruit from young trees.

The canopy volume of the 50 P and 50 AT trees increased from 2.7 to about 5.4 m³ after 4 years growth; however, much of the lower foliage removed to provide access for the digger was not replaced. These trees were flowering when transplanted and retained some fruit until maturity from this bloom. Yield increased each year and the cumulative yield of these trees over the 4 years was a clear advantage for this treatment.

The 4-year performance of the 30 AT trees was the poorest. These trees increased their height and volume, but proportionately less than the other trees. They were columnar in shape after pruning and largely retained this form (Fig. 2). Soon after transplanting they shed more leaves and fruit than the 50 P or 50 AT trees. Yield of the 30 AT trees was similar to that of the SP trees but was less than that of the 50 P and 50 AT trees at the end of the experiment, despite a slight numerical advantage in tree height and canopy volume.

To the grower, the successful mechanical transplanting of fruiting citrus trees involves tree survival and the rapid return of the trees to their pretransplant level of productivity. The degree of canopy pruning as it affected long-term performance, was the only factor which seemed to be of practical significance in this study. All trees in the 2 experiments survived transplanting without developing an inordinate level of water stress or any apparent detrimental effects from water stress at transplanting. This suggests that tree survival, as it may relate to short-term water stress, did not warrant major concern during transplanting. Practices used to prevent water stress only do not appear to be necessary in environments similar to those experienced in this study. Instead, emphasis should be placed on canopy regrowth and yield.

Tree productivity, while recovering from the canopy pruning treatments, was not directly proportional to the amount of foliage removed. Trees with the least amount of foliage removed did not produce the most fruit. This result supports the concept of achieving the correct "balance" between the root and shoot systems as apparently represented by the 50% canopy-pruned trees in this study. Using these trees as the basis of comparison then, the severely pruned trees were overpruned. This treatment, as compared to the others, may have provided some additional advantage in tree survival, but it was accompanied by an un-
necessary loss in yield. The trees with 30% foliage removed (30 AT) were underpruned. The slow recovery and generally poor performance of these trees indicated that this treatment is probably the least desirable commercially.

It can not be concluded that removing 50% of the canopy will always be the optimum treatment; however, it is a reasonable starting point. Adjustments could be made by taking into consideration other potentially important factors not included in this study, for example, tree age and rootstock. If trees younger than those used here were transplanted, then a larger part of the root system would be enclosed by the digger and proportionately less of the canopy would need to be pruned. Trees on different rootstocks vary in root distribution and vigor (4, 5, 6, 9), characteristics which could affect the rate of root regeneration as well as canopy regrowth.

In summary, 8-year-old ‘Murcott’ trees on rough lemon were transplanted successfully with a mechanical tree digger. The amount of foliage removed prior to transplanting had a significant effect on yield for a period of 4 years after transplanting, with 50% canopy removal being the best treatment. Application of an antitranspirant, and root pruning, did not provide any short- or long-term benefit.

**Literature Cited**