without overheating and slowly release it at night thus retarding the decrease in trunk temperatures. The wrap would also have high insulating value to retard heat transfer at night and would be made of material that inhibits light interception by the trunk. The wrap would be easy to install and maintain, relatively inexpensive, last for at least 3 years, and would not retain water. Tree wraps currently available that have many of these favorable characteristics but still lack the cold protection qualities of a soil bank.

Additional index words. Citrus sinensis.

Abstract. Freeze damaged, 2-year-old ‘Hamlin’ orange (Citrus sinensis (L.) Osb.) trees on trifoliate orange (Poncirus trifoliata (L.) Raf.) rootstock were used to study the influence of tree wraps on light intensity, trunk temperature, and sprouting underneath various wraps in the spring of 1985. Six wrap treatments were applied to 36 trees on 26 Feb., 1985 as follows: unwrapped, fiberglass, Reese, Reese modified to exclude light, white Tree Guard, and charcoal Tree Guard. Light and temperature were measured during several days in March 1985, and sprouts from the lower 16 inches of the trunks were counted and weighed on 13 May, 1985. Light intensity, daytime trunk temperatures and spraying were greatest for unwrapped and white tree guard wraps. The charcoal Tree Guard produced higher daytime and lower nighttime trunk temperatures than fiberglass wraps, but no light or spraying were measured under these wraps. Numbers and dry weights of shoots were similar between Reese and modified Reese wraps although there was a 10-fold difference in light underneath these wraps. Therefore, wraps that excluded light and/or moderated trunk temperature fluctuations were superior to other wraps with respect to trunk sprout inhibition of freeze damaged trees.

Tree wraps not only provide cold protection for young citrus trees during the winter (4, 7, 8) but also influence trunk sprouting in the spring. Trunk sprouting on freeze damaged trees may be beneficial or deleterious, depending on the degree of injury sustained by the canopy. Following less severe freezes, ample canopy wood may survive and produce new shoots. In this case trunk sprouting would be undesirable, occurring at the expense of growth in the tree canopy. However, severe freezes may kill a young tree nearly to the bud union, and the development of trunk sprouts is necessary for the reestablishment of the tree canopy. In either case, absence or presence of a tree wrap and the type of wrap become important factors in the regrowth and proper training of the young citrus tree.

Sprout inhibition by wraps may be a result of a physical barrier imposed by a close fitting wrap, and/or modification of the environmental factors influencing sprout growth such as temperature and light intensity. Shoot initiation and growth are strongly temperature dependent in citrus (1, 2, 6, 9), and light is necessary for shoots to become autotrophic and to continue growth once initiated. The temperature and light regimes underneath wraps have not been studied in the early spring when sprout initiation and development occur. Moreover, the influence of various trunk wraps on trunk sprouting has not been critically examined in citrus. The objective of this study was to monitor the temperature and light environment of young citrus tree trunks underneath various wraps during early spring, and to examine the relationship between these environmental factors and trunk sprouting in freeze damaged trees.

Materials and Methods

Two-year-old ‘Hamlin’ orange trees on trifoliate orange rootstock located at Gainesville, Florida were used in this study. These trees were protected from severe freezes during the 1984-85 winter with fiberglass trunk wraps and microsprinkler irrigation, but were killed back to a height of ca. 2 feet. On 26 February, 1985, fiberglass wraps were removed and 6 wrap treatments applied to 36 trees in a randomized complete block design as follows: unwrapped (UW), fiberglass (FG), Reese (R), Reese modified to exclude light (RM), white Tree Guard (WT) and charcoal Tree Guard (CT). These treatments were chosen to provide for separation of light and temperature effects on trunk sprouting. The wraps covered the lower 16 inches


LIGHT INTENSITY, TRUNK TEMPERATURES AND SPROUTING OF WRAPPED AND UNWRAPPED YOUNG ‘HAMLIN’ ORANGE TREES FOLLOWING A FREEZE

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Additional index words. Citrus sinensis.


of the trunk, of which ca. 14 inches was scion wood. Most trees had sprouts above the wrapped portion of the trunk at this time, but no sprouts were observed on the lower 16 inches.

Trunk temperature was measured with copper-constantan thermocouples taped to the trunk at an 8-inch height. Air temperatures were measured with thermocouples suspended on canopy wood ca. 3 feet above the ground. Light intensity was measured with Li-Cor quantum sensors taped to the trunk near the thermocouples. Due to a shortage of quantum sensors, light intensity could only be measured on 3 of the 6 treatments during any particular day. Therefore, temperature and light intensity measurements were made over a 20 day period in March, 1985, the quantum sensors being moved among treatments on different days. Temperatures were measured hourly and light intensities at 15 min. intervals.

Sprouts from the lower 16 inches of the trunks were removed and counted on 13 May, 1985, after treatments had been in place for 77 days, and placed in an oven at 176°F for 24 hr for dry weight determination. Temperature, sprout number and dry weight data were analyzed for treatment differences using analysis of variance and Duncan's multiple range test. Although light intensity data could not be analyzed statistically, data for any particular treatment on different days with similar sky conditions were comparable.

Results and Discussion

Generally, trunk temperatures under WT and CT wraps were highest and those under R and RM wraps lowest during the daylight hours, with FG, UW and air temperatures intermediate (Fig. 1). However, in the afternoon on cloudy days, all wrapped trunk temperatures were generally higher than the air temperature, but differences among wrap treatments were small and varied from hour-to-hour. In mid-afternoon on sunny days, differences in trunk temperatures between WT and RM treatments approached 30°F, and temperatures under WT wraps reached 105°F. In addition, temperatures remained above 100°F under WT wraps for 3-4 hr, while temperatures under RM wraps generally remained below 85°F. During the night, temperatures under the R and RM wraps were highest, lowest for WT, CT, UW and air, and intermediate for FG. By sunrise, the temperatures under the RM wraps were significantly higher (1-2°F) than all other treatments. This is probably a result of the covering of black tape used to exclude light which made the wrap airtight, thus a better insulator than the R wrap which was ventilated. Although statistically different, it is questionable whether a 1-2°F difference in nighttime temperature is of biological significance to a young tree with respect to trunk sprouting.

Light intensity varied from ambient on unwrapped trunks to undetectable levels on trunks of FG and CT treatments. The WT wrap allowed the most light through (9-13% of ambient) followed by R (4-9% of ambient) then RM (less than 0.1% of ambient) (Fig. 2). Light intensity in the UW, WT and R treatments was well above the reported light compensation point for citrus (5) which is ca. 1-2% of full sunlight.

Unwrapped trunks had highest sprout numbers and dry weights of all treatments (Table 1). The WT treatment had statistically similar numbers of sprouts to UW trunks, but these sprouts were deformed and had lower dry weights than those in UW treatment. Apparently this was due to the physical limitations on sprout growth imposed by the wrap. All other treatments had statistically similar sprout numbers and dry weights, although no sprouts were found on any of the trunks in the FG and CT treatments. It is possible that sprouts had developed somewhat but were abscised before 13 May in the FG and CT treatments due to the lack of light. Small etiolated sprouts have been observed under fiberglass wraps (Davies, unpublished).

Some light (as low as 0.1% of ambient as in the RM treatment) is necessary for full development of trunk sprouts on freeze damaged trees. Furthermore, there was a direct correlation between light intensity and sprout growth. This is supported by the fact that trunks receiving the highest light intensities (UW and WT) had the highest number and dry weight of sprouts, trunks receiving no measurable light (FG and CT) had no sprouts, and treatments receiving intermediate intensities (R and RM) were intermediate in sprout number and dry weight.

Closer analysis of the data suggests that a light intensity-temperature interaction exists and may explain the results found in this study. For example, the CT/WT treatment pair and the R/RM treatment pair were designed to create similar trunk thermal regimes but different light regimes. The WT and CT treatments both had relatively high mean temperatures but different light regimes, while the R and RM treatments both had relatively low mean temperatures but different light regimes. Large differences in sprouting occurred between the WT and CT treatments, suggesting that light intensity influences sprout development given a relatively high trunk thermal regime. On the other hand, no statistical differences in sprouting occurred between the R and RM treatments, suggesting that light intensity does not control sprout development given a relatively low trunk thermal regime. Therefore, the effect of light intensity on sprouting was either strong or nonexistent, depending on the trunk temperature regime.

In general, light was necessary for trunk sprouts to develop and persist under the various wraps, and both high light intensity and high temperature favored the development of trunk sprouts. In relative terms, if the temperature was high but light intensity low (as for CT), or temperature low and light intensity high (as for R), or both temperature and light were low (as RM) then the number and dry weight of sprouts were reduced. Therefore, wraps that exclude light entirely are probably best for trunk sprout inhibition of moderately damaged young citrus trees where regrowth will occur on surviving canopy wood. If trees have been killed to the wrap, however, removal of the wrap at the earliest reasonable date would encourage development of trunk sprouts which will produce a new canopy.

The range of trunk temperatures encountered in this experiment (60-105°F) was above the 55 threshold which qualitatively controls budbreak (6, 9) and below the 120°F threshold which can cause tissue damage in citrus (3, 6). Prolonged periods of trunk temperatures above 100°F as observed for some wraps in this study might adversely affect cambial activity and ultimately the growth of a young tree. Alternatively, such wraps may induce earlier resumption of cambial activity in the spring by raising trunk temperatures to levels favorable for growth. Further studies on the influence of tree wraps on growth of young trees are warranted due to the widespread use of wraps for protection from cold, herbicide, and fertilizer damage.

### Literature Cited


### Table 1. Numbers and dry weights of trunk sprouts on freeze damaged young 'Hamlin' orange trees on 13 May, 1985 influenced by various trunk wraps.

<table>
<thead>
<tr>
<th>Wrap type</th>
<th>Trunk sprouts (no.)</th>
<th>Dry weight (oz.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unwrapped</td>
<td>8.4 a</td>
<td>0.30 a</td>
</tr>
<tr>
<td>White Tree Guard</td>
<td>5.8  a</td>
<td>0.11 b</td>
</tr>
<tr>
<td>Modified Reese</td>
<td>1.5  b</td>
<td>0.05 b</td>
</tr>
<tr>
<td>Reese</td>
<td>1.3  b</td>
<td>0.09 b</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>0.0  b</td>
<td>0.00 b</td>
</tr>
<tr>
<td>Charcoal Tree Guard</td>
<td>0.0  b</td>
<td>0.00 b</td>
</tr>
</tbody>
</table>

*aMeans followed by the same lower case letter are not significantly different at the 5% level according to Duncan's multiple range test. (n=6).*